Materials in Design Engineering

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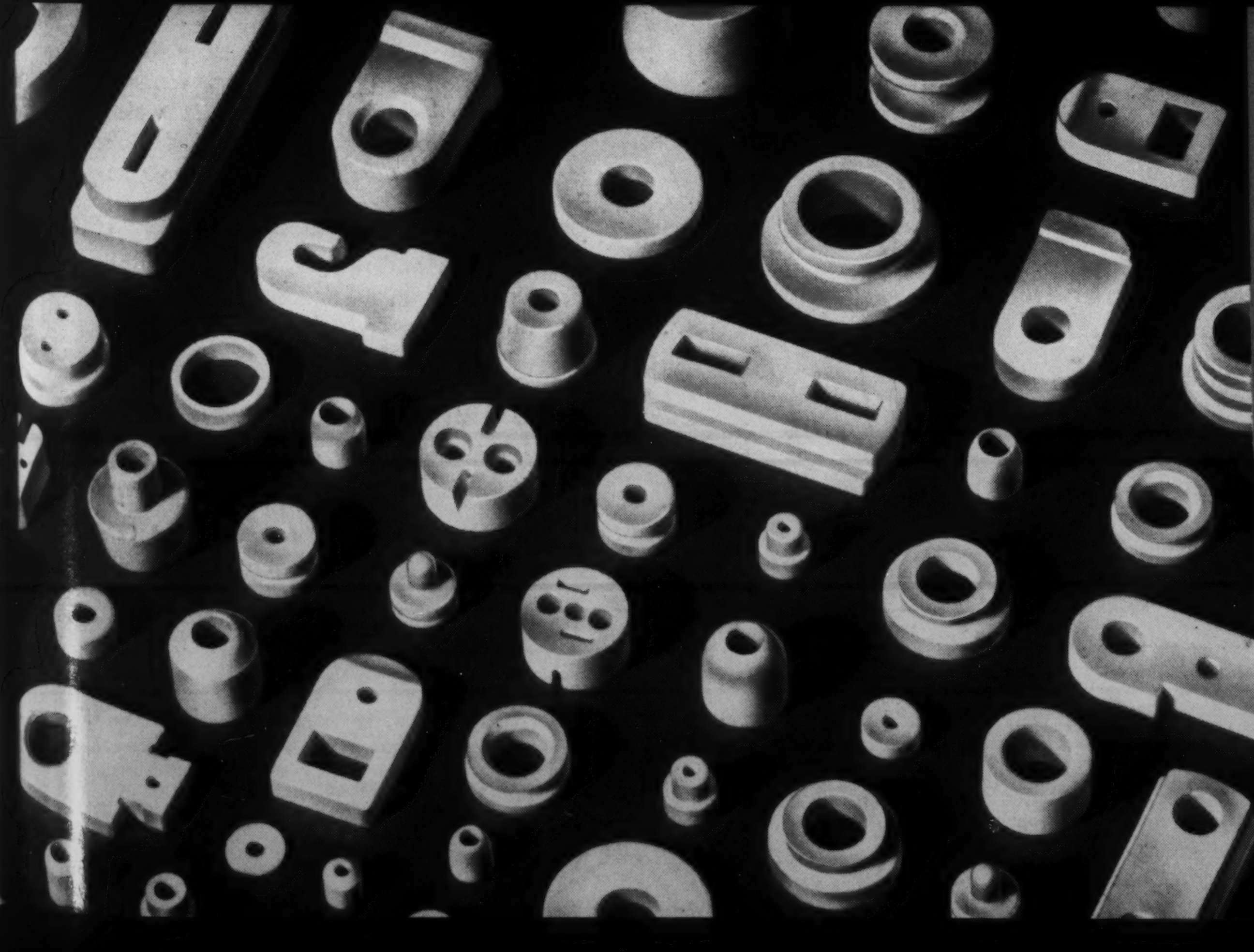

NEW DEVELOPMENTS IN CERAMICS

MANUAL NO. 148

ALSO:
THE CUPRO-NICKELS

WATER-THINNED LATEX PAINTS

COMPLETE CONTENTS PAGE ONE

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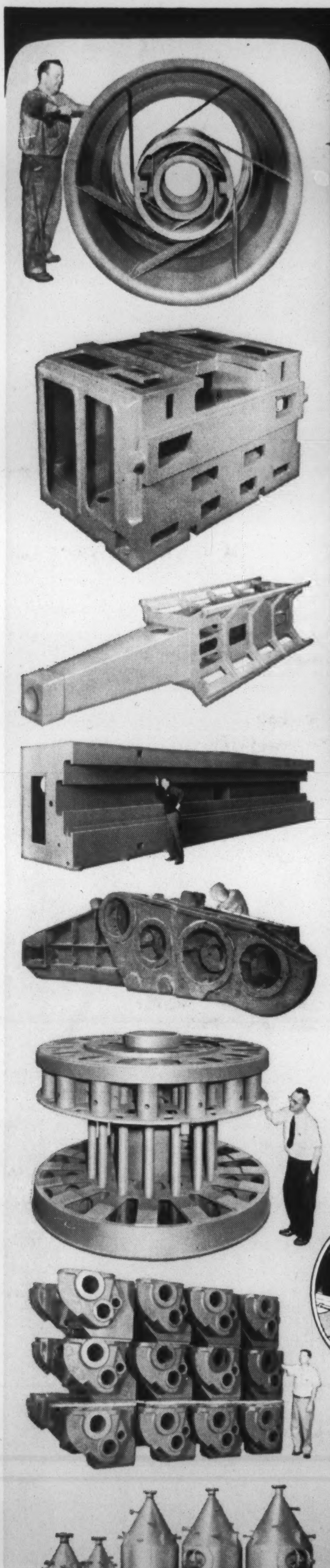
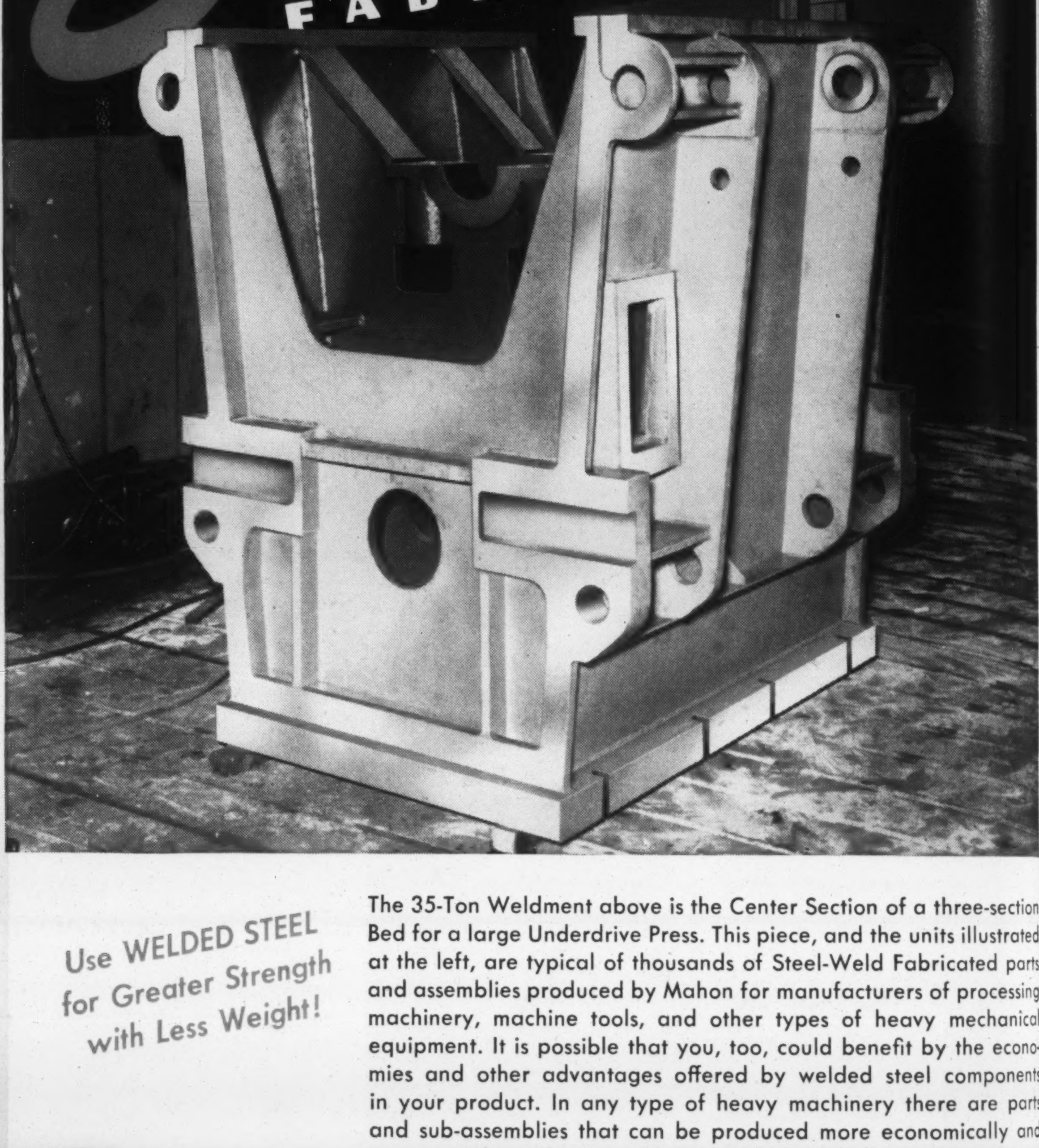


Steel-Weld FABRICATION



Use WELDED STEEL for Greater Strength with Less Weight!

The 35-Ton Weldment above is the Center Section of a three-section Bed for a large Underdrive Press. This piece, and the units illustrated at the left, are typical of thousands of Steel-Weld Fabricated parts and assemblies produced by Mahon for manufacturers of processing machinery, machine tools, and other types of heavy mechanical equipment. It is possible that you, too, could benefit by the economies and other advantages offered by welded steel components in your product. In any type of heavy machinery there are parts and sub-assemblies that can be produced more economically and more satisfactorily in welded steel, because, in weldments you get greater strength with less weight, plus the additional advantages of greater rigidity and predictability. Before you place an order for weldments, you will want to discuss your requirements with Mahon . . . because here is a unique source for welded steel in any form . . . a reliable and responsible source with complete facilities for design engineering, fabricating, machining and assembling . . . a source where advanced fabricating techniques are supplemented by craftsmanship which assures you a finer appearing product embodying every advantage of Steel-Weld Fabrication. See Sweet's Product Design File for information, or, better still, have a Mahon sales engineer call at your convenience.

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Materials

in Design Engineering® *formerly Materials & Methods*

Selection & use of metals, nonmetallics, forms, finishes

MAY 1958
VOL. 47, NO. 5

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New blower...its cast Inconel hub takes stresses of 3500 RPM spin in hot corrosives

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Inconel alloy provides a high combination of strength and corrosion resistance at high temperatures.

Inco foundry casts critical hub

Buffalo Forge took no chances with the most critical part in the blower. To be *sure* that exacting specifications were met, they had the makers of Inconel alloy make the hub casting. As long-term customers of Inco's Bayonne, N. J. foundry, they knew they could depend on Inco to produce a sound, uniformly strong casting; one that would bring out the best that was in the alloy.

Take a tip from Buffalo forge...

When you design for extreme conditions, consider the properties of Inconel alloy. And, if the part is to be cast, call on Inco to cast it.

A 9-page Inco technical bulletin, "Engineering Properties of Cast Inconel Alloys", gives the data you need... compositions, physical properties, machining procedures, and much more. We'll be more than glad to send you a copy.

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What's new IN MATERIALS

...AT A GLANCE

BLACK COLORED STAINLESS STEEL SHAPES, such as toys, signs, sporting goods, metal furniture and appliances, can be formed after coloring without impairing the surface, according to the producer. The color is put on by a new process that chemically bonds colored pigments to a treated stainless steel surface. The process also shows promise for the coloring of aluminum, plain carbon steels and other metals, and will ultimately be available in a range of colors. (More details next month.)

RUBBER PARTS WITH IMPROVED HEAT RESISTANCE may be realized by using a newly developed halogen-containing, isobutylene-base polymer. According to the producer, a cured sample of the rubber withstands 400 F for 40 hr in an air circulating oven, compared to only 2 hr for cured samples of natural and styrene-butadiene rubbers. Other features: good ozone resistance, fast curing, and good compatibility with natural and synthetic rubbers. Potential uses include mechanical goods, conveyor belts and steam hose, as well as truck and passenger tires.

VERY STRONG JOINTS BETWEEN DISSIMILAR METALS are said to be produced by a new nickel-cobalt-base welding wire that permits automatic and manual inert-gas welding of more than 95% of all dissimilar metal combinations. Weld deposits are said to have good impact and corrosion resistance and good resistance to temperatures as low as -310 F. (More details next month.)

A POLYETHYLENE-CARBON BLACK COMPOUND shows promise as an effective insulating and jacketing material for wires, cables, pipes and tubes. The producer says the material can be compression and transfer molded into a variety of shapes. The plastics compound, formed as a result of chemical crosslinking between polyethylene and a carbon black, is said to have good resistance to heat, low temperatures, solvents and weather.

ELECTRODEPOSITION OF TEFLON ON A VARIETY OF MATERIALS can now be done by using an aqueous colloidal dispersion of the material. The method is especially useful for parts that cannot be coated by conventional TFE coating techniques. According to the producer, the electrodeposited coating is nonporous, exhibits no pinholes, and is uniformly deposited around corners and exposed ends of parts. (More details next month.)

ECONOMIES IN COPPER SHEET PRODUCTION may be possible by using a new technique which continuously casts tough pitch copper in "cakes" measuring 25 ft long by 36 in. wide by 15 in. thick; conventional copper cakes are usually 36 to 92 in. long, 25 to 36 in. wide and 4½ to 7 in. thick. According to the producer, the longer lengths will permit rolling mills to roll more copper per hour with a consequent gain in plant efficiency and a reduction in operating costs.

A POWDERED EPOXY RESIN FOR FLUIDIZED COATING is now available in limited quantities. According to the producer, metal, ceramic and glass parts can be coated by first heating the parts, then dipping them into the suspended epoxy powder which melts and clings to the parts. The fused epoxy coating is said to have good dielectric strength (more than 500 v per mil), high heat distortion point, low moisture absorption and good impact strength. (More details next month.)

'EXPLORER' USES A FLAME SPRAYED CERAMIC COATING to protect its payload of instruments from severe temperature extremes. The coating, an aluminum oxide ceramic, was sprayed on in stripes along the outside of the instrument vehicle from the nose cone down to the fourth stage rocket motor section. The 1/4-in. wide stripes are said to keep temperatures inside the American satellite between 50 and 86 F even though temperatures on the outside vary from -150 to 600 F every hour of its travel in space.

A CORK-RUBBER GASKET MATERIAL WITH GOOD SEALING PROPERTIES has been developed for applications where neither cork composition nor cork and rubber have been completely satisfactory. The material, made with a new "continuous phase" elastomeric binder that surrounds and embeds the cork particles, is said to seal liquids and gases at flange pressures as low as 100 psi and as high as 4000 psi. The producer says the material has greater resistance to fluids than most resilient gasket materials because the binder closely approaches cork in chemical inertness.

Turn to page 141 for more "What's New in Materials"

MATERIALS BRIEFS

Dog Boots

Black and red boots, slush molded from two vinyl resins, are now available in four different sizes to fit the paws of all dogs from toy manchesters to boxers. The vinyl boots are said to protect dog's paws from ice, snow, rocks, mud, burrs and thorns.

Labels for Babies

Metal clamps may eventually replace plastics beads and other devices in identifying newborn babies. The metal clamp is attached to the baby's umbilical cord at the instant of delivery with a pair of pliers which stamp the initials of the doctor and the mother on the clamp.

Aluminum Bookbindings

Black and silver aluminum fabrics make up the covers for a new 30-volume set of history books. The metallic bookbindings are said to be durable and good-looking.

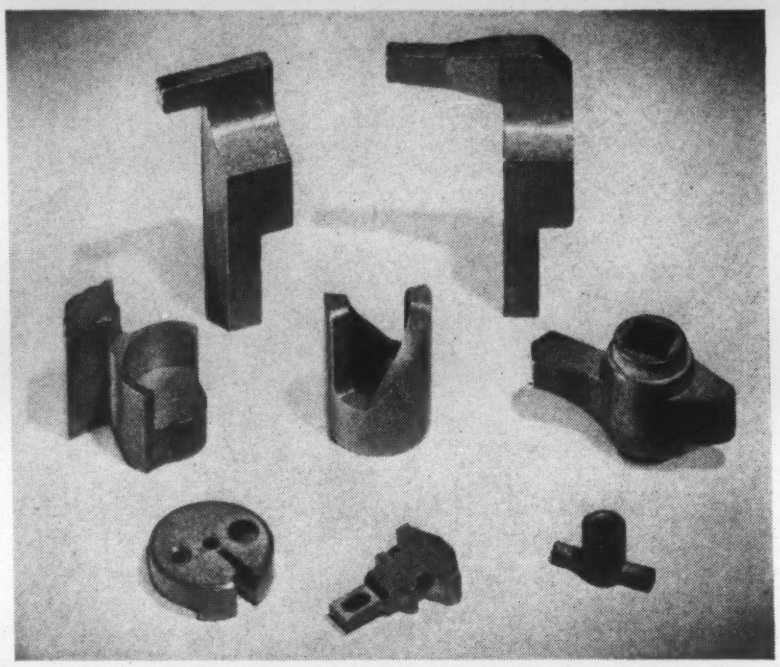
Built-In Flavor

Scotch flavored wood, taken from the staves of casks in which Scotch whiskey has aged for many years, is used in the construction of small sherry decanters and barrel-shaped mugs. The mugs are bound with copper hoops.

Warmer Trips for Toes

A combustion-type heating unit made entirely of stainless steel has been developed to supply instant heat to the interiors of cars operating in cold weather. The unit heats the engine coolant to 160 F, then transports it to the car's regular heater.

MULTI-PART PERFORMANCE
AT ONE-PART COST...



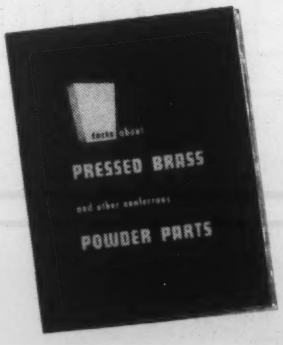
...an outstanding advantage of
BRASS POWDER METALLURGY

These complicated shapes are made as one-piece metal powder sinterings. They are manufactured to very close tolerances and designed to function with a high degree of precision.

Each one of these metal powder parts is made at substantially lower unit costs than would have been possible by ordinary machining or as a multi-piece assembly.

By designing for brass powder metallurgy, there are other advantages:
. . . ***elimination of secondary machining***
. . . ***high durability of parts in use***
. . . ***mass production with uniformly high quality***
. . . ***controlled mechanical properties***
. . . ***parts promptly available.***

It will pay you to consult a powder metal fabricator for his advice on how to incorporate these advantages in your products.



THIS BOOKLET
will assist you in evaluating this modern production method in terms of your particular needs.

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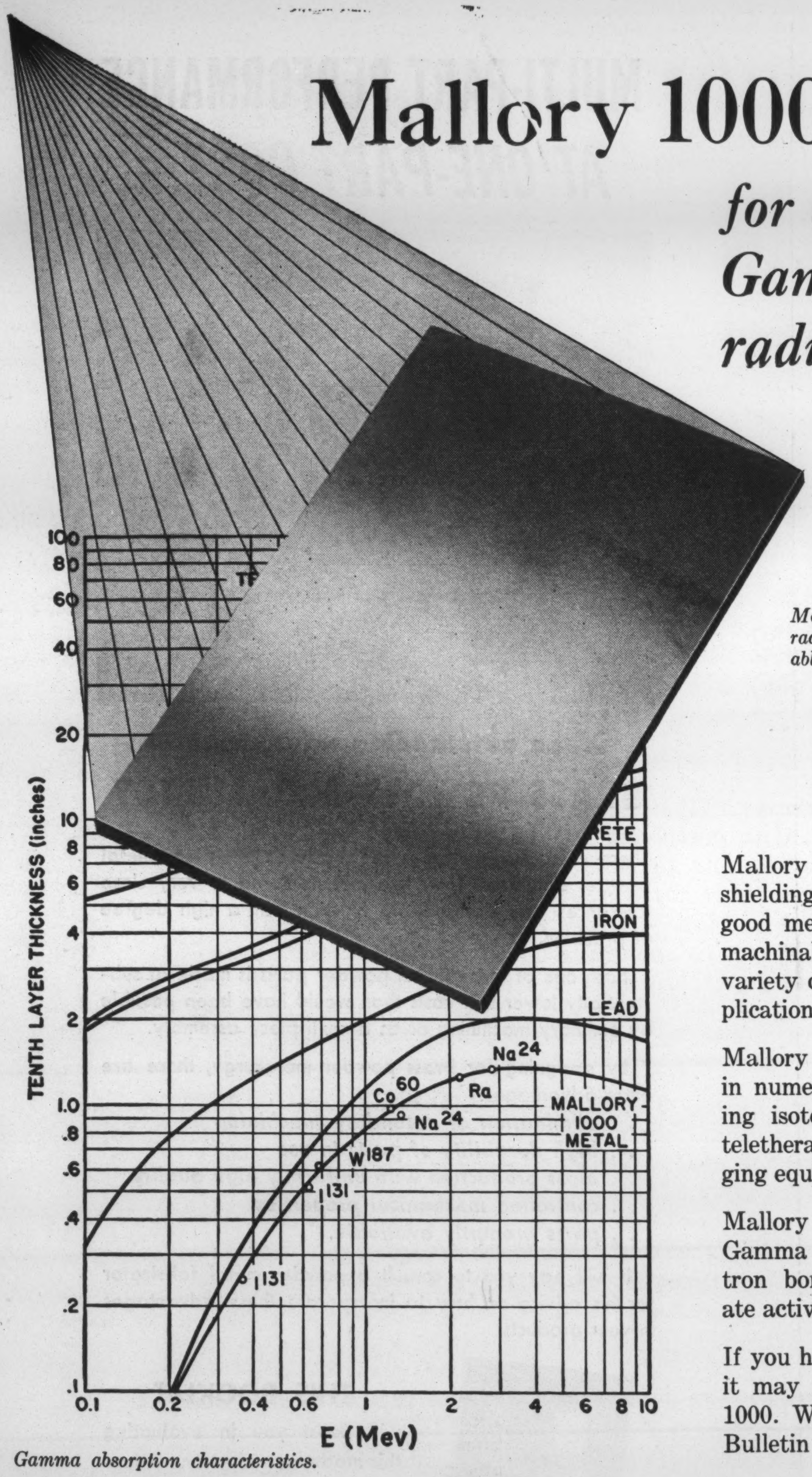
Mallory 1000 Metal

for effective Gamma radiation shielding



Mallory 1000 "slab" for radiation shielding available in sizes up to 6" x 15".

Gamma absorption characteristics.

Mallory 1000 Metal is ideal for radiation shielding applications. It has high density, good mechanical strength, and excellent machinability . . . is available in a wide variety of shapes and sizes for many applications in this field.

Mallory 1000 Metal is already being used in numerous applications such as shielding isotope shipping containers, cobalt teletherapy machines, and oil well logging equipment.

Mallory 1000 Metal effectively absorbs Gamma radiation . . . low intensity neutron bombardment causes only moderate activity.

If you have radiation shielding problems, it may pay you to investigate Mallory 1000. Write for your copy of Technical Bulletin 6-7C.

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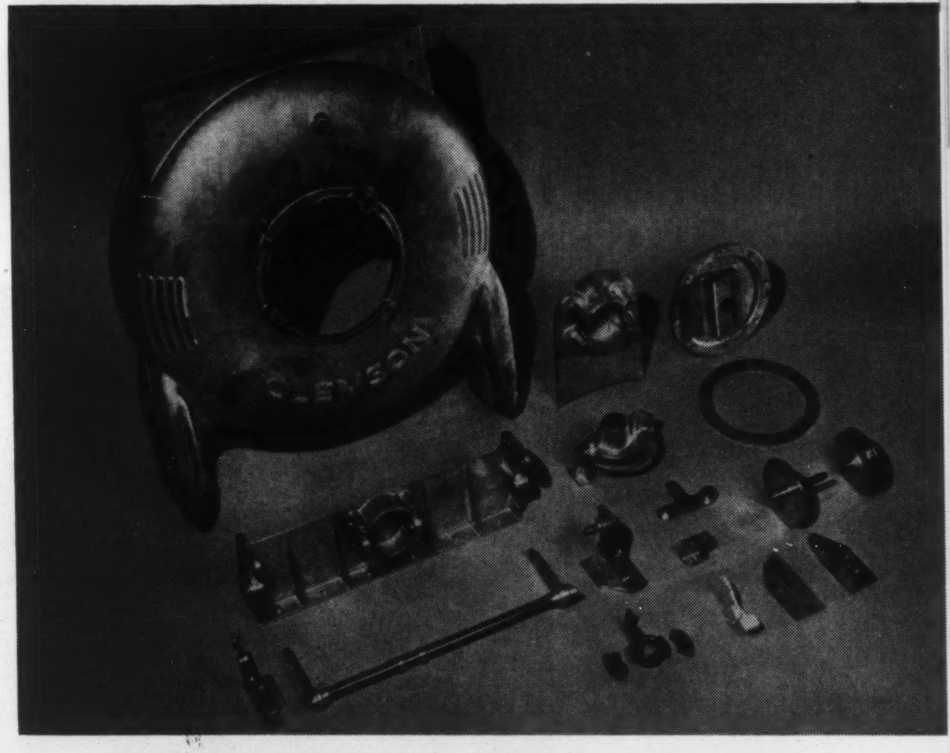
MATERIALS AT WORK

New and interesting applications of engineering materials

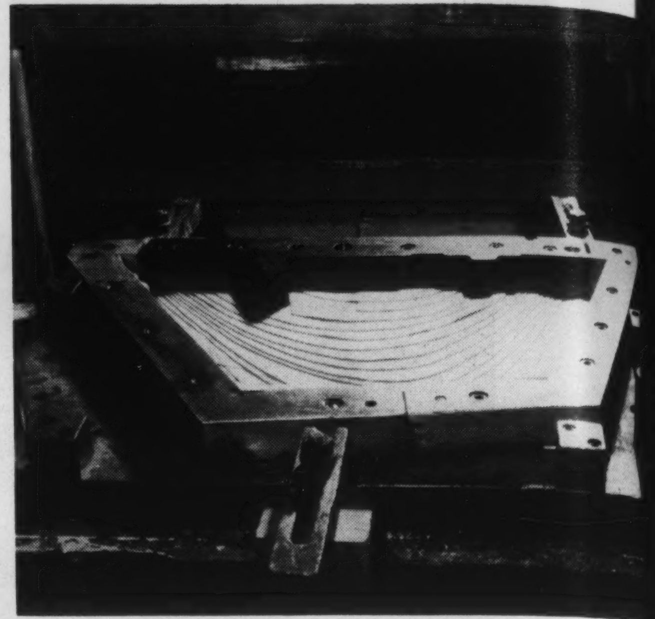


19 aluminum and zinc die castings reduce weight, cost of lawn mower

Use of 19 aluminum and zinc die castings has resulted in substantial improvements in the design of a new 21-in. self-propelled lawn mower (see top photo). According to the American Die Casting Institute, any other method of production would have necessitated a greater number of parts and hence ". . . comparable quality could not be achieved at comparable cost."

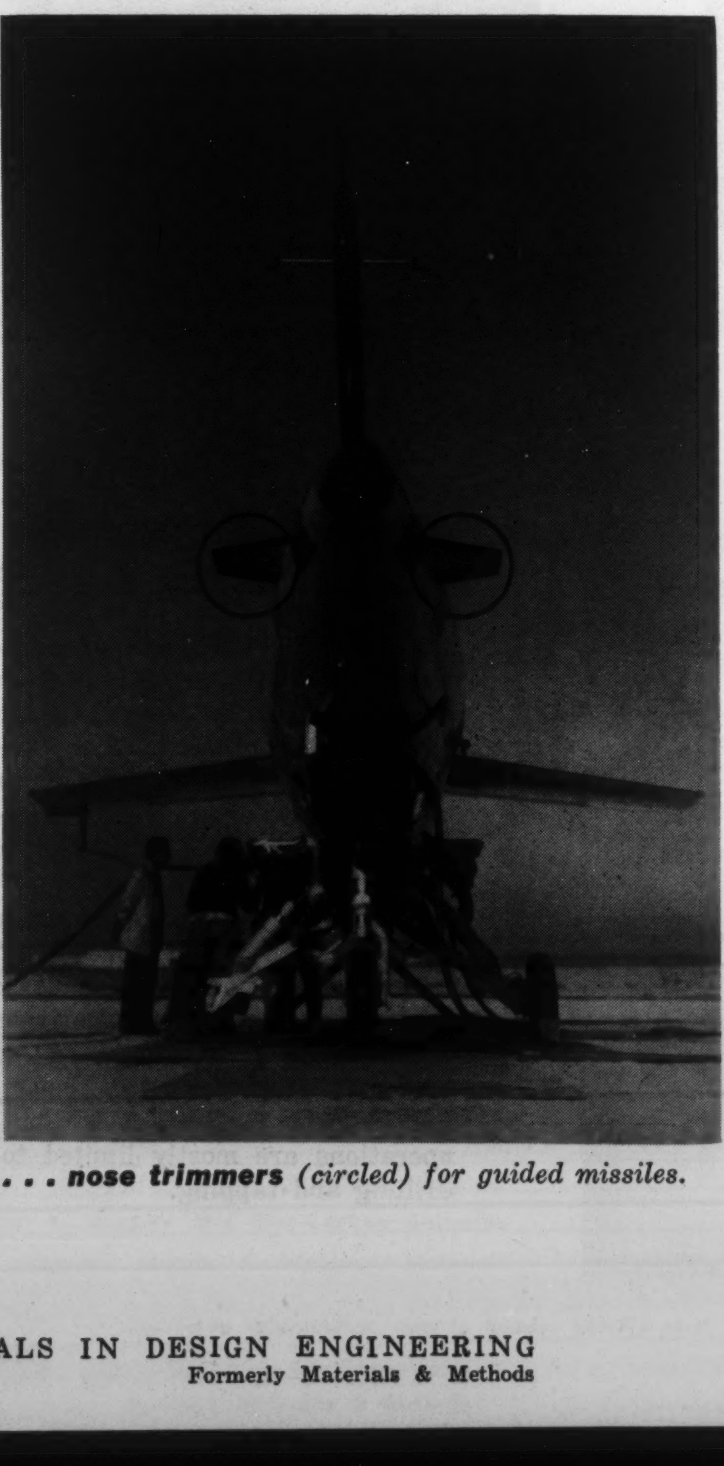
Aluminum was selected for the larger castings in order to keep weight to a minimum; zinc was selected for the smaller castings because it is a relatively inexpensive metal and because it can be cast to extremely close dimensional tolerances. In spite of the many studs, bosses, holes, recesses, and gear and ratchet teeth (see bottom photo), secondary operations are mostly limited to simple broaching, drilling and tapping.

Patterns *of resin-impregnated glass cloth are cut, dried and . . .*



. . . ***placed in die*** *and molded into . . .*

Molded reinforced plastic solves design problem



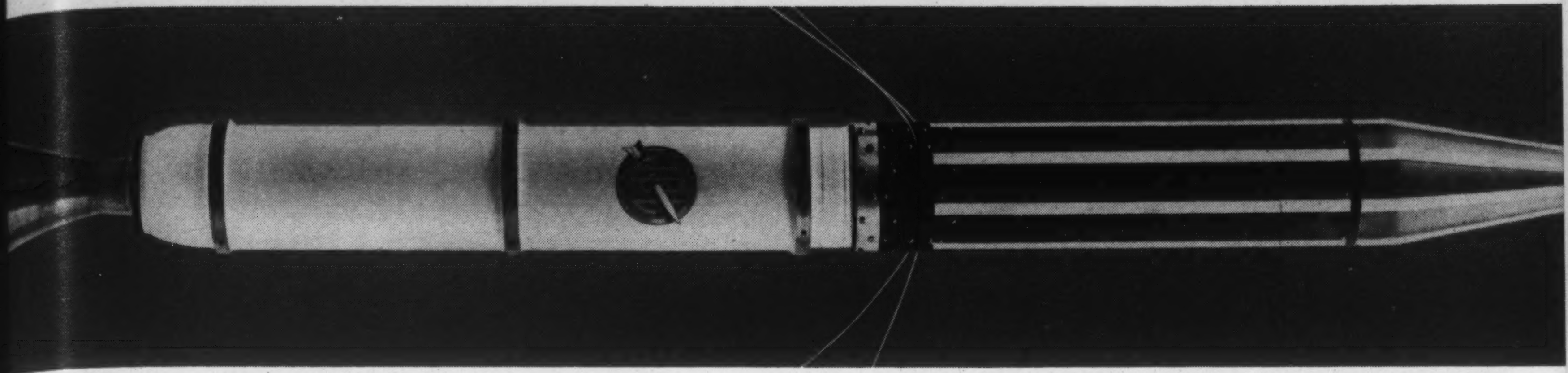
. . . ***nose trimmers*** *(circled) for guided missiles.*

In fabricating nose control trimmers for the Regulus II guided missile, Chance Vought Aircraft faced a difficult materials selection problem: the 2-ft movable surfaces had to be 1) strong enough to withstand the stresses created at supersonic speeds, 2) tapered in three directions, and 3) made of a material that would not affect radio transmission used to control the missile in flight. Glass cloth-reinforced polyester was found to satisfy all requirements. However, parts machined from it were unusable because exposed edges of the cloth split into layers at supersonic speeds. Therefore, Chance Vought decided to mold the part.

To provide the proper taper, 150 layers of impregnated glass cloth were cut into 50 different patterns and laid up in the die—the thickest section containing the full 150 layers, the edges only six (see photo). The largest patterns were laid out at the bottom, with the smaller ones tapering toward the thick edge for a total of 75 layers. Then the process was repeated in reverse, ending up with the largest on top. The part was then molded in a 150-ton press at 320 F.

AT WORK

U. S. earth satellite got help from . . .



. . . Ceramic stripes

An aluminum oxide coating sprayed on in stripes along the outside of the instrument carrying section (from nose cone to fourth stage rocket motor; see photo above) is performing the essential task of controlling temperatures inside the "Explorer" earth satellite.

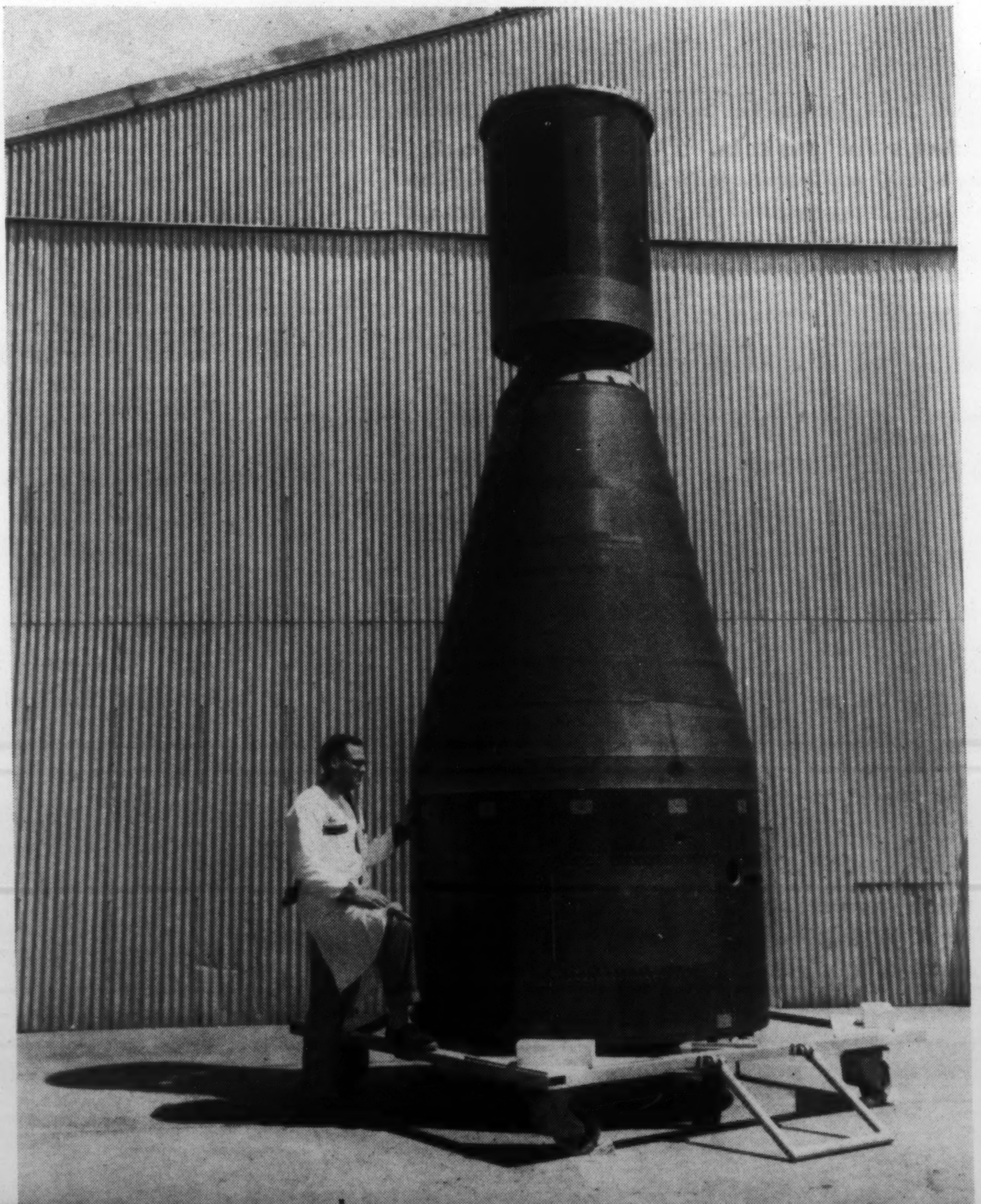
As explained by Norton Co., producers of the ceramic coating material, when the satellite is on the dark side of the earth, it radiates heat; when on the sun side of the earth, it absorbs heat. The temperature differential would normally amount to approximately 750°F—from –150 F on the cold side to almost 600 F on the hot side. These wide fluctuations in temperature would create enormous thermal stresses and strains.

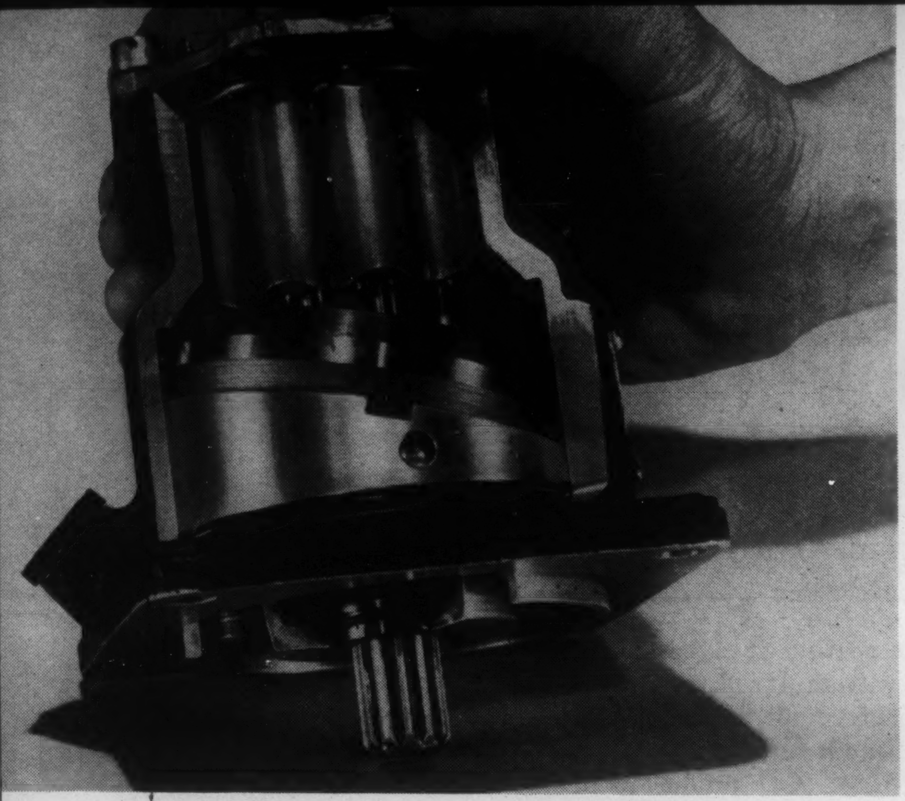
To prevent such great stresses, 25% of the forward shell of the satellite is covered with eight ¼-in. wide, equally spaced stripes of aluminum oxide. By allowing only selected areas of the satellite's surface to absorb and radiate heat, the stripes maintain the temperature range inside the satellite between 50 and 86 F at all times.

. . . Aluminum 'spin-launcher'

One of the problems encountered in the attempt to get a U. S. satellite into orbit was how to keep the second and third stages of the Army's Jupiter C missile on course after the first stage dropped off. According to Reynolds Metals Co., this problem was solved by using the aluminum spin-launcher shown in the accompanying photo.

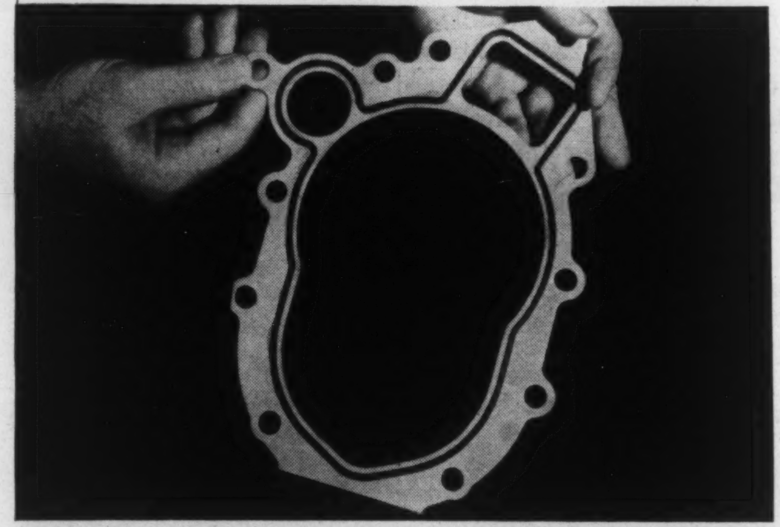
The spin-launcher is actually a special nose section for the first stage of the missile: it holds the second and third stages in the bucket-like container at the top. When the second stage is ready to be launched, the spin-launcher gives it a rotating, or spinning, motion which keeps it on course.





O-ring seals. *This 28-hp motor operates at 6000 rpm at a pressure of 2000 psi. Five Viton o-rings are used to resist the heat and solvents within.*

Coated fabrics. *Viton can be easily spread or calendered onto fabric, and this bladder-type fuel cell for aircraft represents only one of many possible applications. The fuel cells are expected to operate satisfactorily at temperatures ranging from 450 to 500 F.*



Seals for gaskets. *This aluminum gasket is designed for 200 psi service with JP4 and JP5 (jet fuels) at operating temperatures ranging from –60 to 350 F. Viton, slightly thicker than the aluminum plate, insures a tight seal.*

High temperature hose. *Hoses made of Viton are expected to find wide usage in aircraft, heavy industrial equipment, ships and automobiles.*

Viton fluoro-elastomer for high temperature uses

A little less than a year ago (see MATERIALS IN DESIGN ENGINEERING, July '57, p 90) this magazine published an article on a new family of rubber materials (fluoro-elastomers) being developed to meet the more critical heat and corrosion resistance requirements dictated by today's high speed aircraft and missiles. Two of those materials, Kel-F and Silastic LS-3, have been commercially available for some time. A third, Du Pont's Viton, has undergone considerable testing and is now available for applications requiring good performance at

(continued on p 182)

MORE MATERIALS AT WORK

Phenolic adhesive resists fuels 182

Eight die castings in new recorder 184

Stainless water gage won't lose visibility........184

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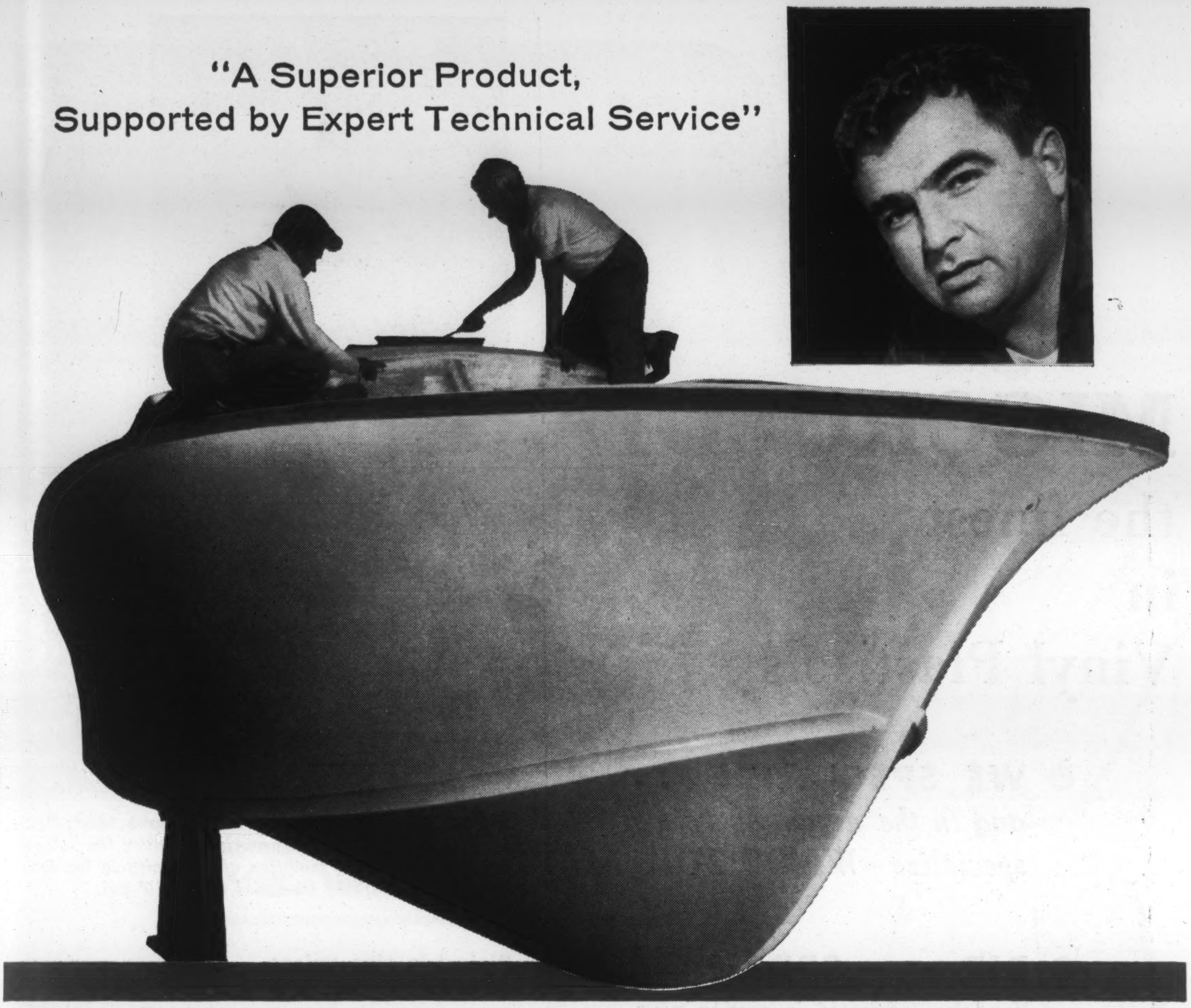

Why the American Hydroplane Corporation Chooses

RCI EPOTUF Epoxy Resins

"We listed the properties we wanted in epoxy materials, and RCI came up with a resin to fit our needs." Speaking is Robert Hobbs, president of the American Hydroplane Corporation, Coral Gables, Florida, an engineering firm specializing in the design and construction of custom and prototype boats.

An unusual case? Not at all. It merely demonstrates the kind of helpful cooperation that you, too, can expect from RCI...*plus* a resin that suits your requirements to perfection.

As Mr. Hobbs put it: "The durability and dependability of RCI EPOTUF Epoxy Resins are very essential requirements in our production, of course. But another important reason why we use Reichhold resins almost exclusively (both epoxy *and* polyester) is the *constant technical service* provided by the Reichhold organization."

Perhaps the several advantages of EPOTUF Epoxy Resins—their toughness, superior bonding, non-running after application – can help on one or more of *your* applications. Add to this two further "plusses"—expert technical assistance and fast delivery anywhere in the country – and you have ample reason for doing business with RCI.

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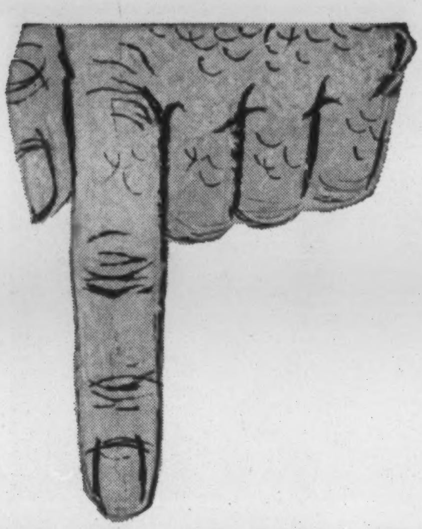

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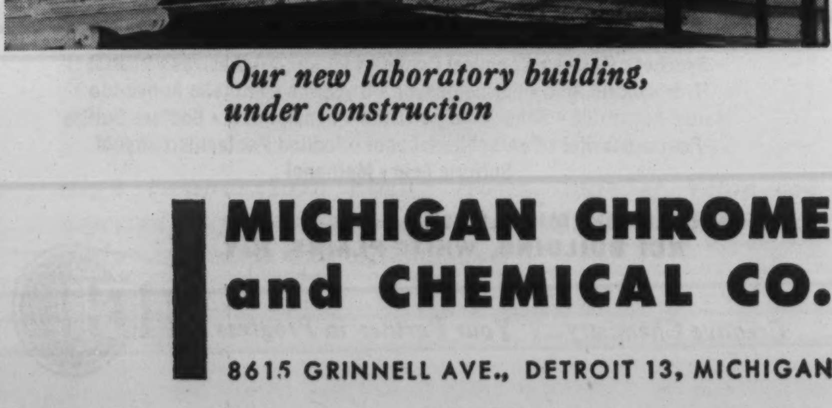

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Letters to the Editor

Glass-reinforced epoxy springs

To the Editor:

I read with interest your article, "Glass-Reinforced Epoxy Springs," Feb '58, p 12. It states that the reason steel was not used was because its modulus of elasticity is too low.

Reinhart and Newman, of the National Bureau of Standards, report development of a glass-reinforced epoxy rod which has a torsion modulus of 10^6 psi. The torsion modulus for steel is about 12 x 10^6 psi. Although the article refers to bending modulus, instead of torsion modulus, the same ratio between steel and plastic should hold. What is the bending modulus of elasticity for this epoxy-glass material?

ALBERT F. SEELIG, JR.
St. Louis, Mo.

The statement referred to should have read: ". . . steel was found to be impractical because the ratio of tensile strength to *modulus of elasticity is too low." The modulus of the material is 5 x 10^6 psi.*

Dielectric pipe unions

To the Editor:

Referring to a letter from C. W. Mason, Dec '57, p 14, I would like to state that I have obtained dielectric unions suitable for connecting galvanized iron hot water tanks to a copper hot water distribution system, and to a galvanized iron incoming line having a bronze shut-off valve and a copper "fill" pipe, from Epco Sales, Inc., 3204 Sackett Ave., Cleveland 9.

The incoming arrangement requires two unions, which is somewhat expensive. I have been informed that it is necessary to install a galvanized to galvanized dielectric union in the gas line as well.

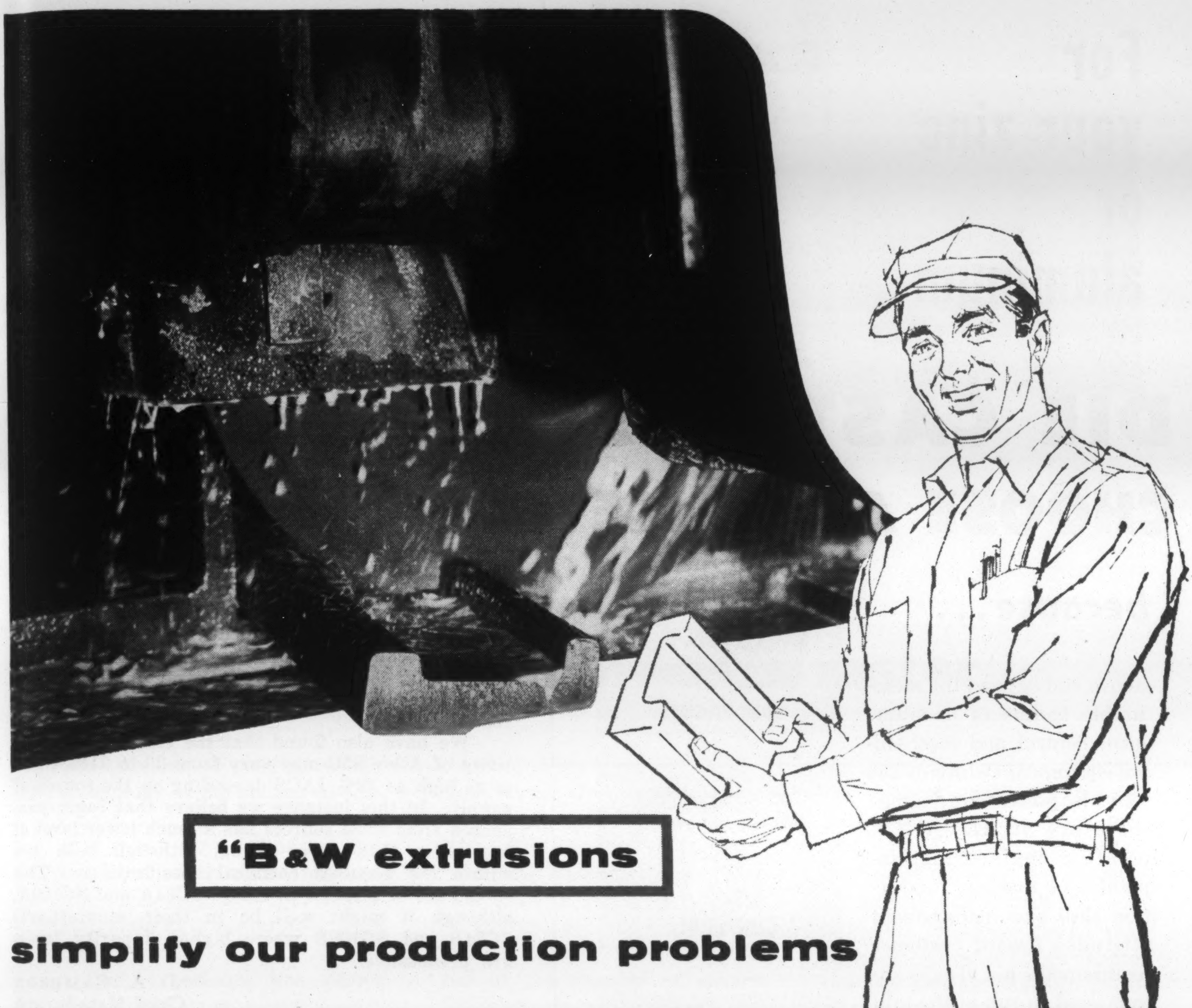
W. E. MCKIBBEN
Euclid, Ohio

Cast aluminum alloy properties

To the Editor:

We are very much interested in Manual 146, "Aluminum Alloy Castings," which appeared in the February issue. We have been working on a problem concerning aluminum alloy die castings and would like to know more about the sources of your data.

Refer to the values listed for electrical conductivity of alloys SC84A and SG100A in Table 2. In the case of Alloy SG100A you indicate that its electrical conductivity is 30% IACS. This is in agreement with the figure listed in the 1950 edition of the Aluminum Co. publication *Alcoa Aluminum and Its Alloys*. The 1947 edition of this publication, however, lists its conductivity as 37% IACS. We have recently purchased a trial quantity of A360, and have made numerous determinations of conductivity



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letters to the editor

on the surface of the ingot and on the cross section of slices removed from the ingot. The results were quite consistent, and averaged out at 37% IACS.

In a similar manner both your table and the later Alcoa publication indicate a conductivity of 25% IACS for SC84A while the older Alcoa booklet quotes 27%. In this instance, we have obtained 30 to 31% on both ingots and die castings.

All of our conductivity determinations were made with a Magnatest conductivity meter. As you no doubt know, this instrument is supplied with test blocks for calibration, and we have further checked it against a Kelvin bridge. We therefore have a high degree of confidence in the accuracy of our test results.

We have also found that the electrical conductivity of Alloy S5C may vary from 30 to 31% IACS to as high as 42% IACS depending on the source of supply. In this instance we believe that ingot purchased from some sources has a much lower level of impurities than other ingots although both are within the required chemical specifications. This should not be a factor in Alloys SC84A and SG100A, although it might well be in their counterparts SC84B and SG100B where higher impurity levels are permissible.

J. A. Cameron
Chief Metallurgist
Elliott Co.
Jeannette, Pa.

The data was supplied by the Aluminum Assn. and represents typical values, not maximum values. Impurities have a great effect, and test values on purchased material will undoubtedly be better than typical and will vary with source.

Electromagnetic shielding material

To the Editor:

We have observed that in certain types of electronic instrumentation there is electromagnetic influence between one element of the circuit and others. It was suggested that we use electromagnetic screens around each element. I have heard that this principle is applied to the recording heads of some professional magnetic tape recorders; a small inverted bucket protects the head from the influence of electromagnetic fields to aid in obtaining a clean register. The material used is Mu-Metal. We would like to know the supplier's name.

J. A. Riess
Celanese Mexicana S.A.
Plaza Santos Degollado 10
Mexico

Mu-Metal is a nickel alloy produced by Telegraph Construction and Maintenance Co., Ltd., London, England. Mr. Riess' letter has been forwarded to International Nickel Co. for additional information.

ONE POINT OF VIE

We need better materials faster

The accelerated pace at which technology is advancing in this atomic and space age has created many new demands. Not the least of these is the need for developing new and better materials at a faster rate than ever before.

Past experience has shown that materials development programs are complex and time consuming. If we are to have materials to meet our changing technological requirements when they are needed, the Government and private industry must try to find ways to shorten the development period. In working out any such program we would do well to benefit from four important lessons of the past.

What the past tells us

First, past experience has shown that planned materials development programs for specific products or projects generally are not worth the effort unless present materials are definitely inadequate. In most cases, engineers cannot wait until an "ideal" material is developed; they have to select from among the available materials those which most closely meet their needs.

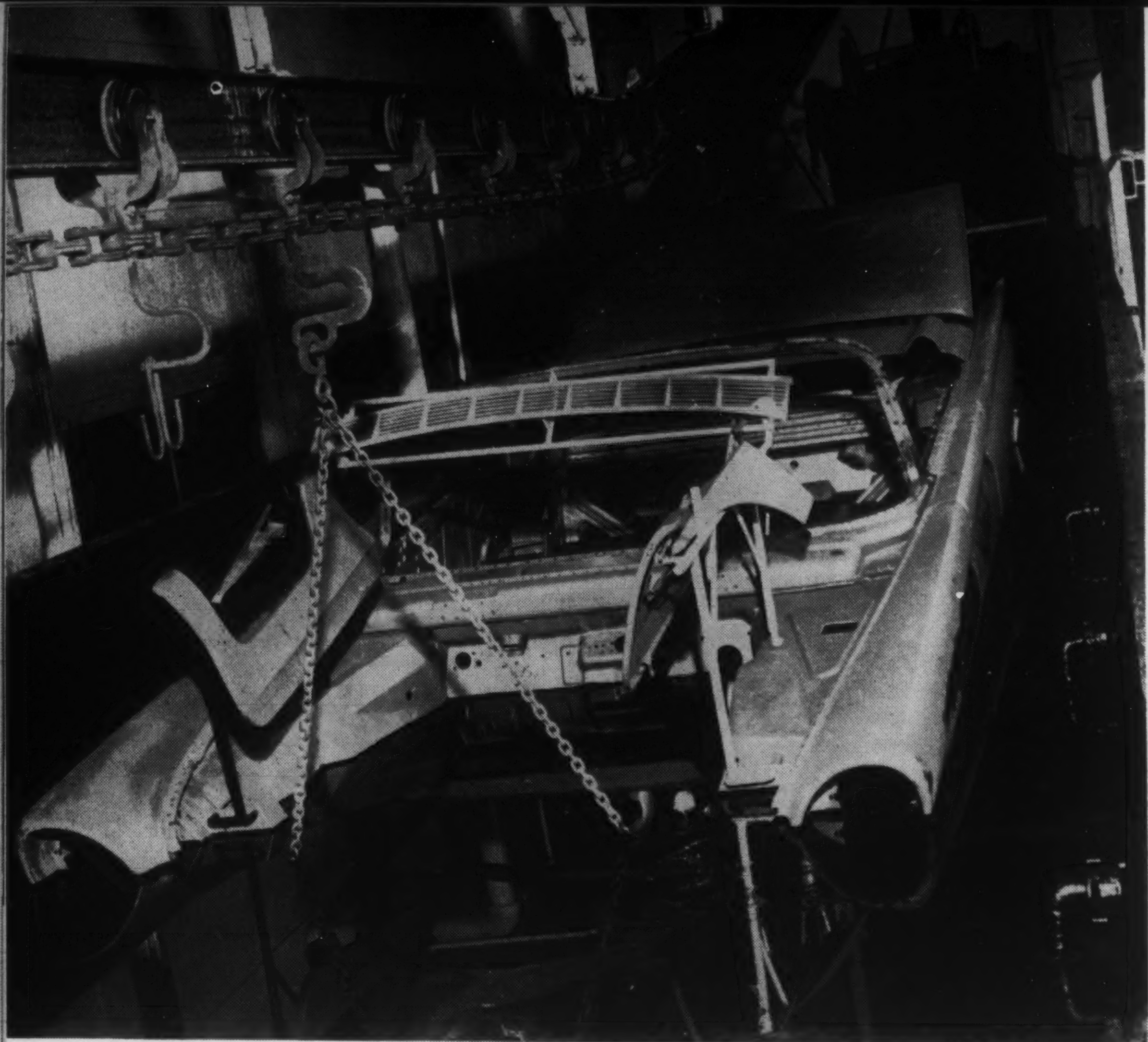
Second, we have learned that as a general rule it is unwise to concentrate too heavily on the development of one material at the expense of others. Titanium is a case in point. On hindsight many authorities agree now that we would be further ahead if the Government had spent less time and money on the titanium program and more during the same period on developing other materials.

Third, we have learned that a balanced materials research effort covering all problem areas is necessary. Until recently, major attention in the weapons and aircraft field was given to developing better high temperature structural materials. As a result, progress in nonstructural materials for high temperature use has lagged. Some experts indicate that the high temperature structural materials now available will be adequate for about the next five years, whereas our present coatings, thermal insulation materials, skin materials and lubricants cannot even meet many of the immediate service requirements.

Fourth, we have found that perhaps the most time consuming and difficult phase in materials development is what has been termed the "learning period." Before a newly developed material can be used successfully, it is necessary to learn how to process and fabricate it, and how to design with it. This has always been a long, slow process. In the case of titanium, it has resulted in years of delay in getting the material into practical use.

Learn these lessons first

This last consideration, in particular, has not received the attention it deserves. But all four of these expensive lessons should be learned before we embark on the speed-up materials programs that will be necessary to assure future technological progress.



Dow Chemical Co.

***Car body** is dipped into tank of styrene-butadiene primer.*

Supplementing an earlier article (Oct '57), this survey covers the three principal types of

Water-Thinned Paints

—How They Compare For Metal Products

by Walter Brenner,
Consulting Chemical Engineer

■ Water-thinned latex paints offer many advantages over conventional organic solvent paints for finishing metal products. Because they are noninflammable, water-thinned paints eliminate the fire hazards normally associated with finishing operations; this factor can be expected to result in lower insurance charges and lower operating costs. These paints also eliminate toxicity hazards and the need for solvent recovery systems which are costly to install and require constant attention.

Because of these advantages, water-thinned latex paints have been receiving considerable attention for large-scale finishing operations, such as automotive and appliance applications. Since wet sanding with water is prevalent in automotive finishing, paints that can adhere to damp surfaces make it possible to eliminate one or more drying operations and achieve higher production rates. In appliance applications, good hardness, durability and color retention are quite important, and water-thinned paints appear to satisfy these critical requirements.

The principal water-thinned latex paints for metals (see Table 1) are based on three different types of polymers: styrene-butadiene, polyvinyl acetate, and acrylic esters. At present, the styrene-butadiene polymer paints are lower in cost than the other two polymer systems.

In addition to cost, such factors as quality, durability and ease of application are important in selecting a finishing system for metal products. Compared to home and building applications, many more factors must be considered when selecting a coating for metals and closer attention must be paid to the end properties of the coating such as hardness, adhesion, solvent resistance, etc.

TABLE 1—A QUICK CHECK LIST OF COATING PROPERTIES

Type ↓	Major Characteristics
Styrene-Butadiene	Lowest cost. Noninflammable. Good adhesion, toughness and hardness. Resistant to water, salt spray, minerals and some chemicals. Good hold-out and sanding properties. Requires high pigment-to-binder ratio to produce high gloss. White or light colored coatings have poor color retention at high temperatures.
Polyvinyl Acetate	Slightly higher in cost than styrene-butadiene paints. Noninflammable. Good air drying properties and good color retention, adhesion and flexibility after baking. Resistant to water, salt spray, lubricating oils, alkalis, acids and many common solvents. Comparatively poor heat resistance.
Acrylic	Highest cost. Noninflammable. Good hardness, flexibility, adhesion and color retention. Resistant to cold and warm water, salt spray, lubricating oils, weathering and aging. Appliance primers have good spraying characteristics and can be wet sanded; however, resistance to soap solutions, detergents and hot water is comparatively poor.

TABLE 2—PROPERTIES OF TWO CLEAR STYRENE-BUTADIENE PAINTS[a]

Application Conditions:		
pH	4	8
Catalyst	None	0.07% Co
Bake	275 F, 30 min	275 F, 30 min
MECHANICAL PROPERTIES		
Knife Adhesion	Excellent	Excellent
Flexibility (bent over ⅛-in. mandrel)	Crazed	Crazed
Impact Resistance, in.-lb	<2	<2
Pencil Hardness	5H	3H
CHEMICAL PROPERTIES		
Resistance to Mineral Spirits (1 hr)	OK	OK
Water Resistance		
1 Hr	OK	OK
24 Hr	Sl whitened	OK
1 Wk	Whitened, sl blistered	Sl whitened, sl blistered
Resistance to 3% Sodium Hydroxide		
1 Hr	OK	Sl brittle
24 Hr	OK	Sl brittle
Resistance to 5% Acetic Acid		
1 Hr	OK	Brittle
24 Hr	OK	Brittle

[a]Basis metal: cold rolled steel.

Industrial Latex Paints: A Progress Report

Within a period of 10 years water-thinned latex paints have gained a market of 60,000,000 gal, or about 10% of paint sales in this country. Most latex paint is used in homes and buildings because of the ease with which it can be applied, and because of its slight odor, quick drying and easy clean-up properties. Water-thinned paints have gained close to 60% of total flat wall paint sales. They also are used in over 50% of exterior masonry applications.

Except for a few special applications, water-thinned latex paints have not been used in industrial applications on metal surfaces to any great extent. Greater use has been held back largely because of corrosion problems, lack of adhesion, and poor gloss, color stability, hardness and water resistance.

In the past three years or so, however, many of these problems have been overcome, and it appears that noninflammable water-thinned industrial latex paints are on the verge of widespread use. The potential for these paints is almost unlimited. It has been forecast that by 1961 they could account for 25% of all industrial paint sales. Even this estimate may prove to be quite conservative, especially if some of the developments which are now under intensive development are brought into production.

It has been reported, for example, that at least two of the big three auto manufacturers plan to have cars coated with water-thinned primers under road test evaluation in 1959. It has also been reported that a target date of 1962 has been set by some manufacturers for the complete conversion to water-thinned paints. The consequences of such a conversion and the impetus it would provide to other applications can be readily appreciated.

Styrene-butadiene paints

Water-thinned styrene-butadiene latex paints have been used for many years in architectural applications. In the past year or so, however, a specially designed latex that shows considerable promise has been developed for metal products. (For complete details on this coating see "Water-Thinned Paints for Metal Products," M/DE, Oct '57, p 137.)

The new latex system consists of a colloidal dispersion of resin particles in water and is supplied at an acid pH of 4.0±0.5. By means of heat and catalysis the butadiene groups in the polymer react to form a thermosetting coating with good adhesion, toughness and hardness, and good resistance to water, mineral spirits and some chemicals.

Typical properties of clear coatings are shown in Table 2. Despite their hardness after baking the coatings have good adhesion and flexibility. The impact resistance of clear coatings is comparatively poor; however, the impact resistance of pigmented automotive primers is comparable to that of standard alkyds.

Automotive and appliance primers

Several automotive and appliance baking primers have been developed and are now under test. In general, the automotive primers are noted for their good spraying characteristics and good hold-out, adhesion, and sanding properties. They also possess good salt spray resistance.

Styrene-butadiene primers are usually applied to phosphate treated steel. Film thicknesses vary from 1.2 to 2.2 mils, depending on pigment content. Typical bake schedule for an iron oxide primer is 30 min at 275 F.

White appliance primers spray easily to a thickness of 1.0-1.2 mils and can be covered with a solvent-type white appliance baking enamel topcoat after a short bake of 10 min at 140 F. These coatings have good adhesion and hold-out properties, and have successfully withstood exposure in a 100% RH, 100 F atmosphere for 1000 hr.

Baking enamels

Both gloss and semigloss baking enamels can be formulated with the styrene-butadiene latex. At this stage of development, properties of these coatings are not generally as good as those of solvent type baking enamels.

In general, the gloss and semigloss coatings are quite similar except that the semigloss coatings are formulated with a higher pigment content. Compared to solvent type enamels, gloss styrene-butadiene enamels require a higher binder-to-pigment ratio to produce a high gloss. Even with pigments having high hiding power, the latex does not have sufficient color retention at high temperatures to permit formulation of white or light colored coatings.

Polyvinyl acetate paints

Considerable progress has been made toward the development of suitable water-thinned polyvinyl acetate paints for metal products. To date, these paints have not reached the same stage of development as water-thinned styrene-butadiene paints and they are being used only on a very small scale. However, several metal primers and gloss paints have been developed and are being evaluated for large-scale industrial finishing applications.

Polyvinyl acetate metal primers are permanently thermoplastic and will soften when heated. A considerable amount of development is being devoted to eliminating this condition. However, it should be noted that no loss in color stability is exhibited by present formulations after prolonged heating.

In many applications, thermoplasticity is not a factor and polyvinyl acetate primers show considerable promise because of their low cost, and their good air drying and baking properties, excellent color retention, and excellent resistance to solvents, alkalis and acids.

Typical of the experimental formulations that have been developed are a black gloss metal primer, a gray metal primer, and a red oxide metal primer.

Black gloss metal primer—This formulation was developed principally for automotive chassis. It is intended for dip or flow application after a 1:1 reduction with water. The coating is distinguished principally for its low cost, which is about $0.85 per gal (raw materials cost). Best gloss and mechanical properties are obtained after baking for 10 to 15 min at 350 F. Gloss values of 80 to 85 units (90 to 95 units is typical for a quality enamel) have been obtained using a 60 deg specular gloss test. Promising results have been obtained with the coating after 167 hr of salt spray testing, and after 1000 hr at a relative humidity of 100% at 95 F.

Gray metal primer—Properties of this coating are quite similar to the black gloss primer. The formulation was developed as an automotive chassis primer and can be cured by air drying or baking. Again raw materials cost is very low—about $0.90 per gal.

Red oxide primer—This coating is intended principally for metal castings and is noted for its low cost and resistance to gasoline oils, and alkalis. In some applications it has been used to replace lacquer coatings. Coated parts have been immersed in gasoline for 8 hr with no evidence of failure. Similarly, no failure is evident after immersion in a mixture of 80% motor oil and 20% kerosene for 500 hr at 300 F. The coating has also withstood 2 min in a boiling alkali solution of 3% trisodium phosphate and 10% sodium hydroxide.

Cost of the red oxide primer is in the range of $1.08 to 1.16 per gal. It can be air-dried or baked.

Acrylic paints

In general, the properties of water-reduced acrylic coatings are quite similar to those of acrylic plastics. The coatings have excellent color retention and water and alkali resistance, and outstanding resistance to deterioration on aging. They are slightly more heat stable than polyvinyl acetate coatings. However, they cost somewhat more than the styrene-butadiene and polyvinyl acetate coatings.

Automotive primers

Most of the industrial acrylic formulations developed to date have been for automotive and appliance applications. A good deal of experimental work has been devoted to red oxide automotive primers. The outlook for suitable gloss topcoats is not too encouraging, at least with present polymers. One of the principal problems of developing suitable primers is price. Figures of $1.50-1.75 per gal have been advanced as being the limit that can be tolerated for primers. This means that the raw materials cost must not exceed $0.75-0.85 per gal—a difficult price to match.

Properties of three principal acrylic automotive primers are shown in Table 3. These emulsions are claimed to provide tough, adherent coatings with excellent resistance to lubricating oils and weathering. No plasticizers are needed, as the coatings are very flexible. They also dry quickly by evaporation and form films even at low temperatures. Another advantage of these resins is their ability to bind large ratios of pigment and extenders without emulsion breakage.

The temperature at which an acrylic film is formed has a distinct effect on properties. A film baked for 30 min at 300 F has better adhesion than one baked at 250 F. Best adhesion is obtained when the primer is air dried, given a topcoat, and then baked.

All of the acrylic primers developed appear to be somewhat

TABLE 3—COMPOSITION AND PROPERTIES OF ACRYLIC EMULSION AUTOMOTIVE PRIMERS[a]

Primer Type ➡	A	B	C
COMPOSITION			
Pigment Composition, %			
Iron Oxide	40	40	50
Barytes	40	40	50
Talc	20	—	—
Acicular Zinc Oxide	—	20	—
Pigment-to-Binder Ratio	70:30	70:30	60:40
Solids Content, %	62.7	63.0	60.0
PROPERTIES			
Knife Adhesion	Excellent	Very good	Very good
Salt Spray Resistance (primer and topcoat; 500 hr, 20% salt sol'n)	Good	Good	Good
Water Immersion Resistance (primer and topcoat; 250 hr at 100 F)	Intense blistering and wrinkling	Unaffected	Very slight blistering
Freeze-Thaw Resistance (5 cycles at 15 F to rm temp)	Sl flocculated	Failed	Flocculated

[a] One coat over automotive sheet treated with phosphate conversion coating. Film baked for 30 min at 300 F.

TABLE 4—PROPERTIES OF ACRYLIC EMULSION APPLIANCE PRIMERS[a]

Type of Primer ➡	E	F	G	Alkyd
White Primer				
COMPOSITION, APPLICATION				
Prime Pigment Composition, %				
Titanium Dioxide	50	50	50	67
Acicular Zinc Oxide	50	50	50	—
Lithopone	—	—	—	33
Pigment-to-Extender Ratio	75:25	50:50	No extender	No extender
Bake Schedule	35 min at 300 F	35 min at 300 F	35 min at 300 F	30 min at 200 F
PROPERTIES				
Dry Sanding Properties	Sl poorer than alkyd	Sl poorer than alkyd	Sl poorer than alkyd	Good
Wet Sanding Properties	Good	Good	Good	Good
Pencil Hardness	2H	3H	2H	2H
Whiteness	Good	Good	Good	Fair
Salt Spray Resistance (816 hr at 95 F, 20% salt sol'n; Navy scale—10 best)	6.0	4.7	5.7	2.7
Water Immersion Resistance (720 hr at 100 F; Navy scale—10 best)				
Blistering	2	2	2	10
Corrosion	7	7	9	9
White Primer Plus Alkyd-Melamine Topcoat				
PROPERTIES				
Pencil Hardness	4H	4H	4H	4H
Adhesion	Good	Good	Good	Good
Impact Resistance, in.-lb	16	20	18	16
Photovolt Whiteness (low values best)	6.09	5.64	7.92	9.20
60-Deg Gloss Value, %	81.8	79.8	80.9	81.3
Salt Spray Resistance (864 hr at 95 F, 20% salt sol'n), in. removed[b]	0.50	0.87	0.83	0.60
Water Immersion Resistance (960 hr at 100F; Navy scale—10 best)				
Blistering	5	8	8	10
Corrosion	8	10	10	10
Cost, $/gal	1.90	1.75	2.27	1.70

[a] One 0.8-mil coat over steel treated with phosphate conversion coating.
[b] Inches removed after stripping with cellophane tape.

softer than commercial oil-based primers. As shown in Table 3, formulation A has excellent adhesion and flexibility and has a higher hardness than the other acrylic primers. A black nitrocellulose lacquer topcoat applied to all of the primers showed no evidence of lifting.

The acrylic automotive primers are also noted for their good salt spray resistance. Primers, either alone or with a topcoat, will withstand 500 hr of salt spray with only slight blistering. However, resistance of the primers to freeze-thaw cycling is not too good. With the exception of formulation A, which showed only slight flocculation, the primers are not very resistant to low temperature cycling.

In distilled water immersion tests (250 hr at 100 F), best resistance is exhibited by formulation B, containing acicular zinc oxide. This compound appears to be necessary in acrylic emulsions to obtain good water resistance.

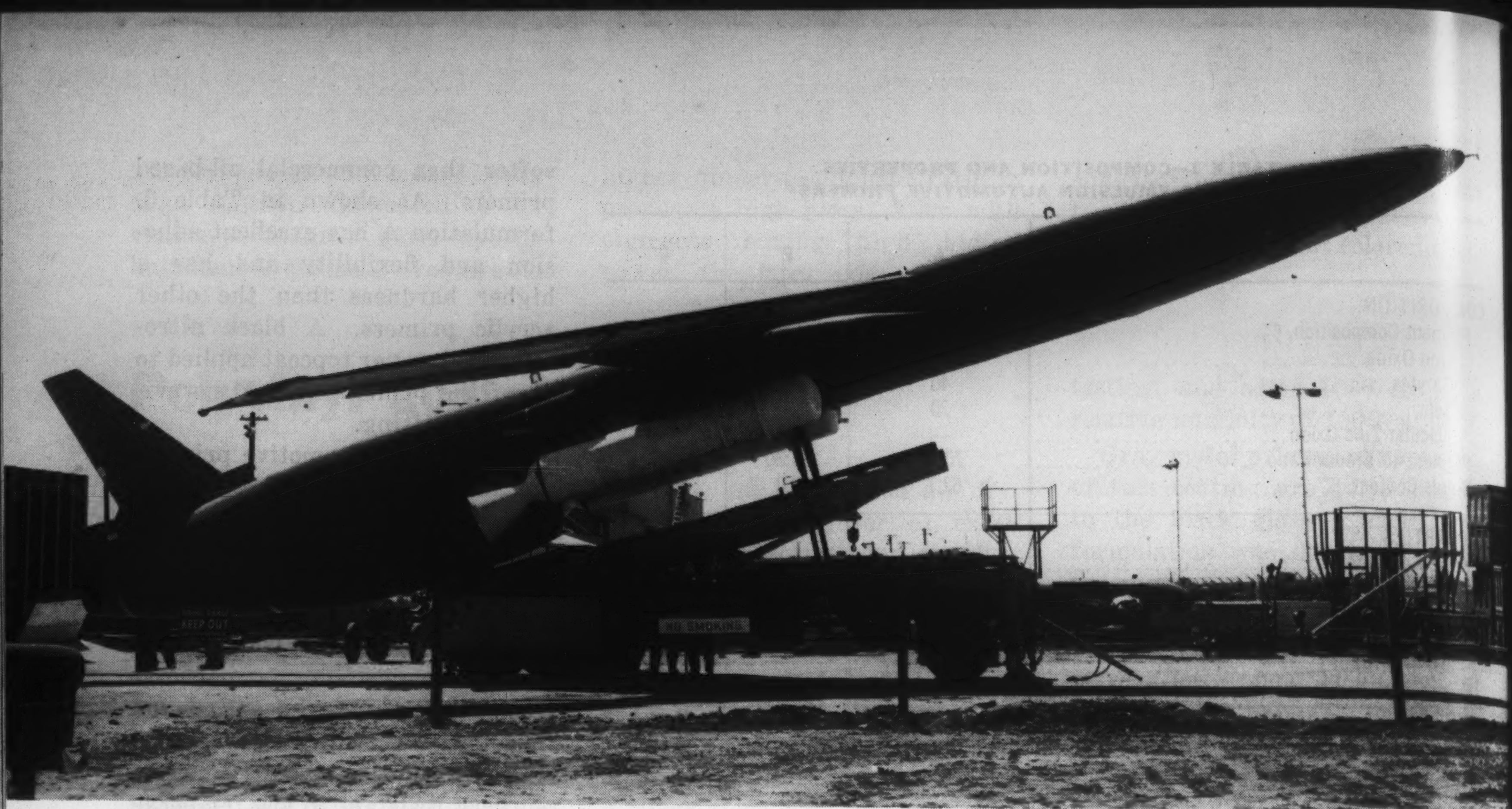
Appliance primers

In addition to automotive primers, a number of experimental acrylic emulsions have been developed for use on refrigerators, kitchen cabinets and similar equipment. As shown in Table 4, the properties of acrylic primers and alkyd primers are quite similar. Note also that formulation F compares favorably in cost with a typical alkyd.

Acrylic appliance primers have good spraying properties, can be wet sanded, and have very good hardness, flexibility, adhesion and color retention. They also have good resistance to humidity and salt spray. However, the primers are not very resistant to blistering when immersed in soap solutions, detergents or hot water; for this reason they cannot be recommended for use on washing machines. The primers also exhibit poor resistance to freezing, but this is not important.

Acknowledgments

The assistance of literature of the following companies is gratefully acknowledged:
Celanese Corp. of America
Dow Chemical Co.
Rohm & Haas Co.



***Missile** components are an important potential use for this new steel.*

Northrop Aircraft, Inc.

New Stainless Steel to Beat Heat Barrier

Developed by the British to withstand the high frictional temperatures encountered by supersonic aircraft and missiles, this modified 18-8 steel can be formed soft, then hardened by heat treatment.

■ A new precipitation hardenable stainless steel that combines high strength, low thermal expansion and good resistance to corrosion has been announced by Firth-Vickers Stainless Steels, Ltd. Designated FV520, it is a modified chromium-nickel steel containing copper, molybdenum and titanium. The material was developed for airframe and skin applications in supersonic airplanes and missiles, and is produced on a tonnage basis.

Forms and treatments

The new alloy is supplied in two slightly modified compositions: B for bar stock, forgings and castings; and S for sheet and strip. The only significant difference between them is the condition in which they are supplied.

Bars and forgings of FV520B are usually supplied in the fully hardened condition, obtained by heating 2 hr at 1380 F, air cooling and reheating 2 hr at 1050 F. In this condition they meet minimum specifications of 112,000 psi yield strength (0.1%) and 134,000 psi tensile strength.

To facilitate machining, however, FV520B bars that have had only the 1380 F heat treatment can be obtained; hardness is about 280 Bhn. After the component has been machined, a final heat treatment at 1050 F will increase the hardness to 310 Bhn. It may be necessary to remove the oxide film by vapor blasting, grinding or pickling after this heat treatment.

Sheet and strip of FV520S can be obtained in the softened condition resulting from air cooling from 1925 F. The soft material has a yield strength (0.1%) of 56,000 psi and is suitable for various forming operations. Although the alloy work hardens rapidly, formed components can be hardened quite uniformly across both cold worked and unworked sections by a relatively low temperature heat treatment. This treatment consists of heating 2 hr at 1375 F, air cooling to room temperature, holding 24 hr, and 1) peak hardening by holding 2 to 16 hr at 840 F, or 2) overaging by holding 2 hr at 1040 F.

Properties

Physical and mechanical properties of FV520 are given in an accompanying table. Particularly noteworthy among the physical properties is the coefficient of

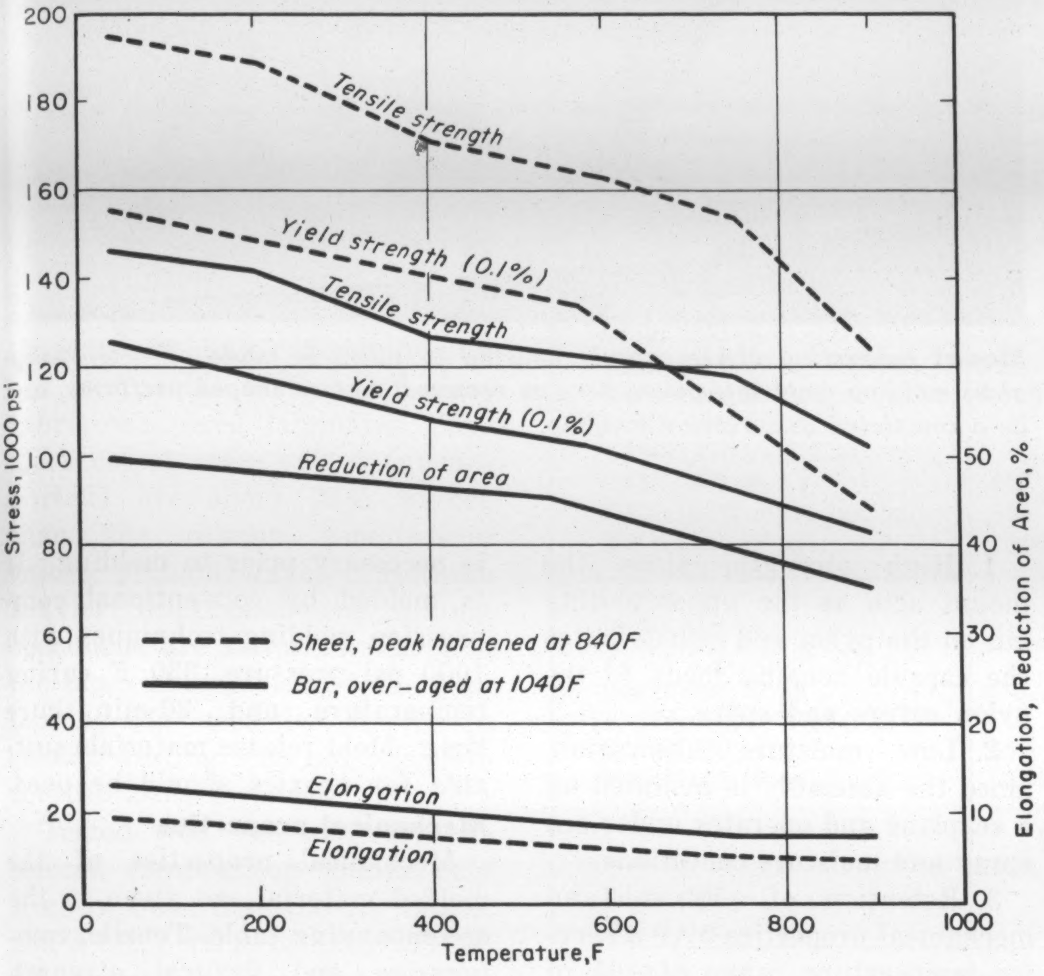


***Fig 1**—Short-time mechanical properties of sheet and bar at elevated temperatures.*

COMPOSITION AND PROPERTIES

COMPOSITION, %	0.07 C, 16 Cr, 6 Ni, 1.5 Cu, 1.5 Mo, 0.3 Ti
PHYSICAL PROPERTIES	
Density, lb/cu in	0.28
Ther Cond (120 F), Btu/hr/sq ft/°F/ft	9.2
Coef of Ther Exp (68-930 F), per °F	7.4 x 10^{-6}
Elec Resistivity (68 F), microhm-cm	85
MECHANICAL PROPERTIES	
Tensile Strength, 1000 psi	
Sheet[a]	124
Sheet (peak hard.)[b]	184
Bar[a]	123
Bar (peak hard.)[b]	184
Bar (over-aged)[c]	152
Sand Cast[d]	144
Investment Cast[e]	147
Yield Strength (0.1%), 1000 psi	
Sheet[a]	45
Sheet (peak hard.)[b]	156
Bar[a]	40
Bar (peak hard.)[b]	157
Bar (over-aged)[c]	138
Sand Cast[d]	123
Elongation, %	
Sheet[a]	46
Sheet (peak hard.)[b]	23
Bar[a]	33
Bar (peak hard.)[b]	19
Bar (over-aged)[c]	23
Sand Cast[d]	20
Investment Cast[e]	8
Reduction of Area, %	
Bar[a]	40
Bar (peak hard.)[b]	52
Bar (over-aged)[c]	58
Sand Cast[d]	47
Investment Cast[e]	12
Fatigue Strength, 1000 psi	
Bar (unnotched, over-aged)[c]	87 (10^8 cycles)
Bar (notched, over-aged)[c]	49 (6 x 10^7 cycles)
Creep Strength (stress to give 0.2% total plastic strain in 1000 hr), 1000 psi	
750 F	74
930 F	27

[a] Air cooled from 1925 F.

[b] Air cooled from 1925 F; 2 hr at 1375 F; air cooled to 60 F in 2 hr; 2 hr at 850 F.

[c] Air cooled from 1925 F; 2 hr at 1375 F; air cooled to 650 F in 2 hr; 1 hr at 1050 F.

[d] Air cooled from 1830 F; 1 hr at 1100 F; air cooled.

[e] Air cooled from 1925 F; 1 hr at 1200 F; air cooled.

thermal expansion, which is comparable with that of low carbon steel and considerably lower than that of 18-8.

Tensile properties can be varied considerably by heat treatment. The softest material is obtained by quenching from above 1900 F. Use of suitable double hardening treatments, given in the table, produces peak hardness or over-aging in wrought material. Castings are produced to a slightly different composition from wrought material and the intermediate hardening treatment is not required.

Short time elevated temperature properties, given in Fig 1, indicate good strength retention to moderately elevated temperatures. Firth-Vickers does not recommend the steel for service at temperatures above 900 to 950 F; the transformation temperature of the steel is about 1100 F.

In the over-aged condition, the new alloy retains good resistance to notched impact loads down to temperatures at least as low as –300 F (see Fig 2).

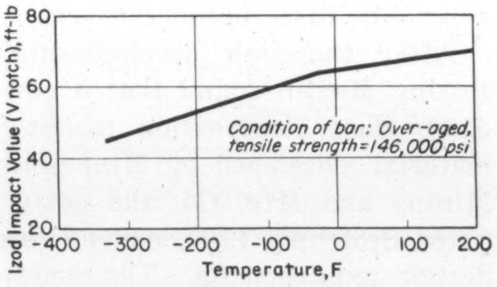


***Fig 2**—Impact strength of bar at various temperatures.*

Corrosion tests in acids and sodium chloride solutions under laboratory conditions indicate that FV520 has corrosion resistance equal to that of 18-8. In addition, the new alloy has excellent resistance to stress-corrosion cracking as shown by tests in high pressure steam at 575 F contaminated with chlorides and caustic alkalis.

Weldability

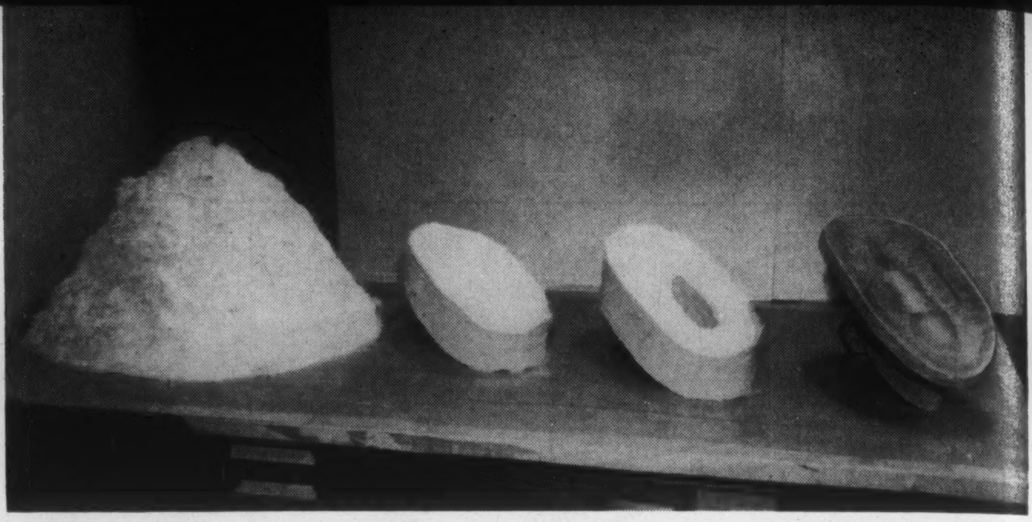
The new steel is weldable without preheat, and no elaborate precautions are required to prevent cracking. There is no tendency for peak hardening to occur in the heat affected zone; maximum hardness adjacent to welds is about 320 Bhn. Heat treatment after welding is not required, but stress relief, if desirable, can be accomplished by a post weld treatment at 1000 F.

New Epoxy-Glass Molding Compound

provides | *High strength*
Structural efficiency
Economical production

by H. J. Doyle and G. F. Molby, *Martin Co.*

Redesigned assembly *is Magnetic Anomaly Detection (MAD) unit mounted on vertical stabilizer of P5M-1 Marlin seaplane.*



Mount *connecting MAD capsule housing to pylon is made of new epoxy-glass molding material, shown here as received, as two shaped preforms, and as a completed compression molding.*

■ In redesigning the housing-to-pylon mount of the MAD assembly (see photo above), the major objectives were to 1) improve strength-to-weight ratio to increase efficiency of the unit, 2) increase production rate and reduce cost, and 3) improve reproducibility of quality.

In addition, the mount itself had to have:

1. High strength, since the mount acts as the upper closing rib on the pylon and redistributes the capsule housing loads to the pylon covers and spars.
2. Low moisture absorption, since the assembly is mounted on a seaplane and operates under sea spray and moisture conditions.
3. Retention of physical and mechanical properties over a service temperature range of –65 to 160 F.
4. Formability of such nature as to permit design flexibility and relatively high production rates.

After thorough developmental testing Martin found that a new epoxy-glass compression molding material, developed by Minnesota Mining and Mfg. Co. and designated Scotchply 1100, met all the design requirements. The material has significantly higher strengths than other types of plastics molding materials and is equivalent in strength to glass fabric-reinforced laminates.

The material consists of 35% epoxy resin and 65% chopped glass fibers of 1⅛-in. length. It is supplied in the premixed, catalyzed condition, and no treatment is necessary prior to molding. It is molded by conventional compression molding techniques with 1000 psi pressure, 330 F curing temperature and 20-min cure time. Mold release materials suitable for epoxies should be used.

Mechanical properties

Mechanical properties of the molded material are given in the accompanying table. Tensile, compressive and flexural strength values are generally high.

Tensile strength of the material in the heavy ½-in. thicknesses is about 32,000 psi, though the data show considerable scatter, with high values up to 47,000 psi. When tested wet, the molding material shows only a slight drop-off in strength from room temperature values. The reduction in strength is 6% for ¼-in. thicknesses, 2% for ½-in. thicknesses.

The average dry tensile value of 32,000 psi (½-in. thickness) is about 8000 psi lower than that of standard (⅛-in.) glass fabric-reinforced laminates. However, since 1) data indicate that ultimate strength is inversely proportional to thickness, and 2) strength reduction for the molded material

The redesign discussed in this article won a Citation in M/DE's Awards Competition and was covered briefly in last month's issue (Apr, p 149).

in the wet condition is very small, the strength of the molding compound is considered comparable to the strength of glass cloth laminates under wet conditions.

Compressive strength values, given only for the heavier thicknesses (½ and ¼ in.), are about twice the maximum value for standard molding compounds and are comparable to those of glass fabric-reinforced laminates. The block compression values (unsupported) are about 25% higher than the column compression values, probably because at these heavier thicknesses the column specimens are acting similarly to the block specimens and the supporting jig used by Martin in column testing was not adequate for the loads involved.

Tested wet, the material has column compression values only slightly lower than the dry values, and a block value of about 55,000 psi, or 10% higher than the dry values.

Flexural strength values at the standard ⅛-in. thickness averages 96,400 psi, which is roughly ten times higher than that of standard molding compounds and substantially exceeds the 50,000 psi specification requirement for glass fabric-reinforced laminates. Tested wet, the material has 80% of its dry flexural strength. Fig 1 shows how ultimate flexural strength varies with the thickness.

Properties of epoxy-glass moldings

AVERAGE MECHANICAL PROPERTIES

Condition ➡	Rm Temp[c]		Wet at Rm Temp		160 F	
Thickness ➡	¼ In.[d]	½ In.[d]	¼ In.[d]	½ In.[d]	¼ In.[d]	½ In.[d]
TENSILE PROPERTIES (1011)[b]						
Ult Str, 1000 psi	31.9	30.3	39.0	29.8	27.6	32.2
Yld Str (0.2% offset), 1000 psi	30.7	27.3	29.5	28.5	27.5	31.4
Mod of Elast, 10⁶ psi	3.39	3.04	3.0	3.24	1.98	2.40
COLUMN COMPRESSIVE PROPERTIES (1021.1)[b]						
Ult Str, 1000 psi	44.7	37.6	39.4	35.0	30.0	32.8
Yld Str (0.2% offset), 1000 psi	38.6	36.3	38.3	33.9	27.2	31.0
Mod of Elast, 10⁶ psi	2.99	3.18	2.79	2.49	2.43	2.52
BLOCK COMPRESSIVE PROPERTIES (1021.1)[b]						
Ult Str, 1000 psi	—	50.0	—	54.7	—	39.3
Yld Str (0.2% offset), 1000 psi	—	49.6	—	54.7	—	41.8
Mod of Elast, 10⁶ psi	—	2.25	—	2.69	—	2.12
FLEXURAL PROPERTIES (1031.1)[b]						
Ult Str, 1000 psi	55.6	48.5	51.7	46.9	47.6	39.4
Mod of Elast, 10⁶ psi	2.44	2.71	2.44	2.75	1.97	2.44
	⅛ In.[d]		⅛ In.[d]		⅛ In.[d]	
Ult Str, 1000 psi	96.4		75.5		56.0	
Mod of Elast, 10⁶ psi	4.42		4.13		2.59	

[a] Scotchply 1100.

[b] Federal Specification L-P-406 test method given in parenthesis.

[c] 73.5 ± 2.5°F; 50 ± 5% RH.

[d] Thicknesses are nominal.

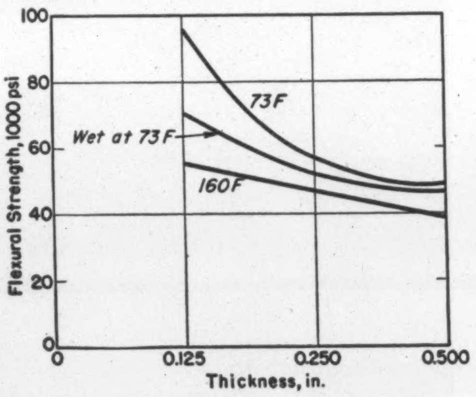


Fig 1—Average flexural strength vs thickness.

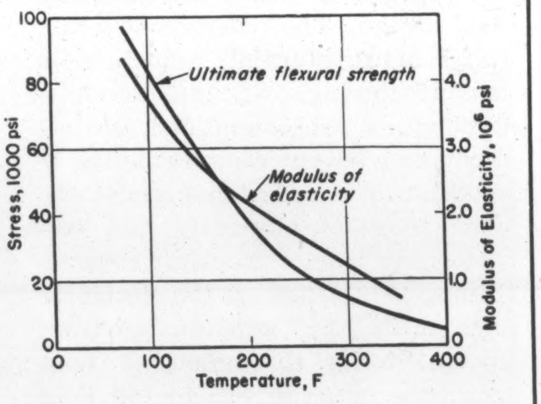


Fig 2—Effect of temperature on flexural strength.

Effect of temperature

Effects of the maximum specification temperature (160 F) on tensile, compressive and flexural strengths are given in the accompanying table. Values are slightly lower than room temperature values. Rigidity values are the most drastically reduced. At 160 F modulus of elasticity in tension is 2.2 x 10⁶ psi or 65% of the room temperature value, in compression is 2.4 x 10⁶ or 80% of the room temperature value, and in flexure is 2.4 x 10⁶ psi or 55% of the room temperature value.

Fig 2 shows the effects of temperatures above the maximum specification temperature on flexural properties of the material. At around 200 F flexural strength falls off rapidly. Above 250 F the curve levels off, with little decrease in strength at temperatures up to about 350 F.

Suitability for fastening

Data from several tests indicate that the material is at least as suitable as glass fabric-reinforced laminates for joining with mechanical fasteners. Fastener determination tests were made using lap-shear fastener specimens with an edge distance-hole diameter ratio of 2D and two 100-deg flush head aluminum alloy rivets with suitable washers. These were adhered in place with an epoxy adhesive which was allowed to cure before testing began.

Tests were conducted in accordance with Federal Specification

Availability

Additional information on Scotchply 1100 is available from Minnesota Mining and Mfg. Co., 900 Fauquier St., St. Paul, Minn. According to the company, the material is now available in commercial quantities.

L-P-406, Method 1051. The testing was drastically curtailed when it was found that the epoxy material would not fail at this loading. All failures were rivet shear failures.

Bearing strength determinations were made in accordance with the same specification, except that edge-distance ratios were varied to include 3D and 4D in addition to the 5D specification requirement. Bearing strength was found to average 85,300 psi for all edge distances tested; differences in edge distance ratios seemed to have no effect. This average value compares with the 35,600 psi value

Redesign of housing and pylon produces more efficient structure

The MAD unit for the Martin P5M-1 Marlin seaplane consists of three components: the capsule housing, the housing-to-pylon mount and the pylon. All three components originally were fabricated by wet lay-up, glass cloth-polyester resin construction.

In redesigning the assembly, Martin replaced this construction with an epoxy-glass compression molding material (see accompanying article) for the mount, and preimpregnated glass cloth-polyester laminating material in the housing and pylon.

The redesigned structure is 30% more efficient, each pound of the new structure supporting 2.21 lb as opposed to 1.69 lb for the original design. The redesign also provides a substantial reduction in manufacturing costs, an increased production rate, simplified fabrication, and better reproducibility of quality. The redesign permits the unit to more efficiently and economically meet its design requirements, i.e., 1) protect the electronic equipment, 2) support environmental loads throughout a temperature range of -65 to 160 F in a salt spray atmosphere, and 3) withstand aerodynamic loads, icing loads and inertia loads resulting from dynamic accelerations during take-offs, landings and flight maneuvers.

Housing-to-pylon mount

The housing-to-pylon mount is located at the upper end of the pylon. It acts as the upper closing rib on the pylon and redistributes the housing loads to the pylon covers and spars.

When fabricated by wet lay-up methods the configuration of the part necessitated excessive chopping and trimming of the glass fabric, resulting in parts of questionable reliability. Also, this operation increased the demands on the fabricator. The mount is now produced by placing a predetermined amount of molding material in a compression molding tool and applying heat and pressure for 40 min. At the end of this brief cycle the completed mount is removed from the mold.

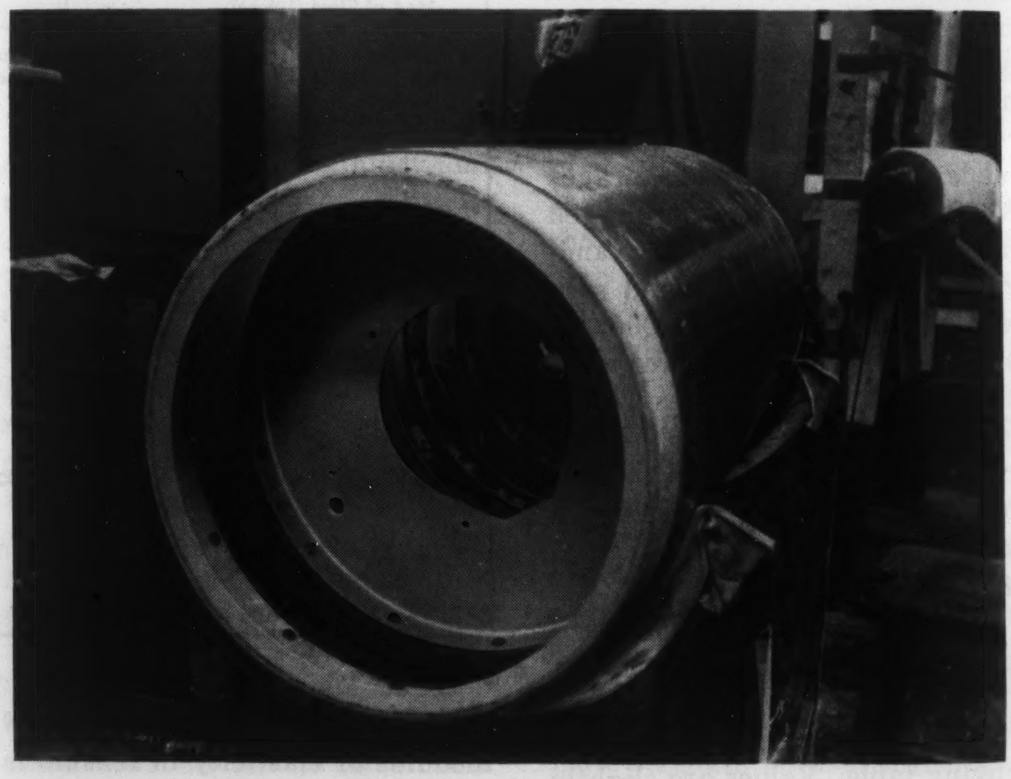
The new epoxy-glass material provides mechanical properties in the molded condition equivalent to those produced by wet lay-up of the polyester-glass cloth laminate. Use of the compression molding technique also substantially increases production speed and greatly simplifies the production process.

Use of the new molding material has increased the production rate from two-thirds of a unit to three units per man-day—an increase of 350% in production rate. Also, the molded mount weighs 10% less than the original.

Housing and pylon

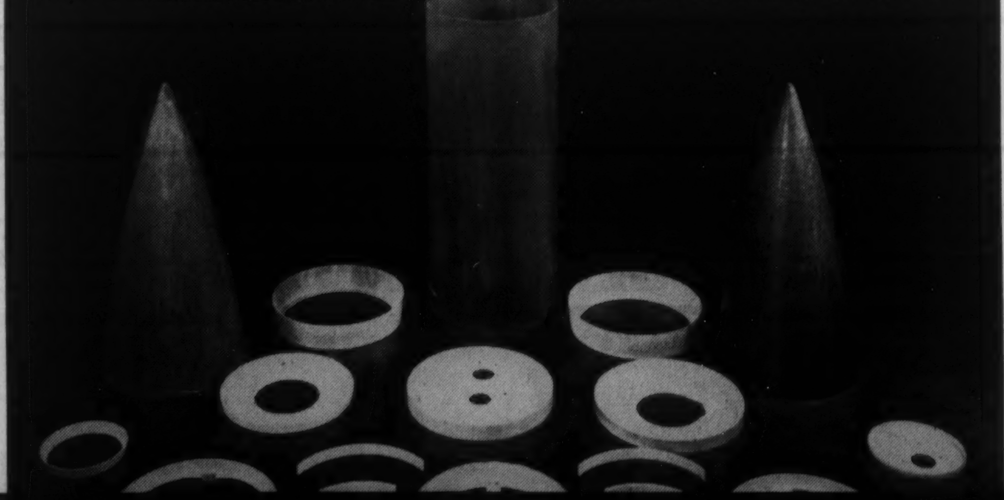
The housing and pylon provide protection and support for the MAD equipment and must meet pertinent military specifications.

The housing capsule



Cylindrical center section, *shown here in close-up, is stabilized with internal ring frames and bulkheads. It supports the major MAD equipment.*

Nose and tail cones *provide aerodynamic fairing for the housing and support the compensating rings and condenser.*



reported by Forest Products Laboratory for glass fabric-reinforced laminates.

Shear strength values (double shear, loaded as a pin) averaged 26,900 psi.

Design variables

Shrinkage determinations indicate that change in dimension from the original mold dimension is nil. The maximum value obtained for panel warpage after molding is less than 0.001 in. Optimum molding pressure was found to be 1000 psi; increases of up to 5000 psi in molding pressure produced lower flexural strength values.

The housing capsule is a semimonocoque shell composed of a cylindrical center section and nose and tail cones. The center section is a cylindrical shell stabilized with internal ring frames and bulkheads and supports the major MAD equipment and the cones. The shell-like nose and tail cones provide aerodynamic fairing for the housing, and support the compensating rings and condenser. The capsule is bolted to the molded mount at the upper end of the pylon.

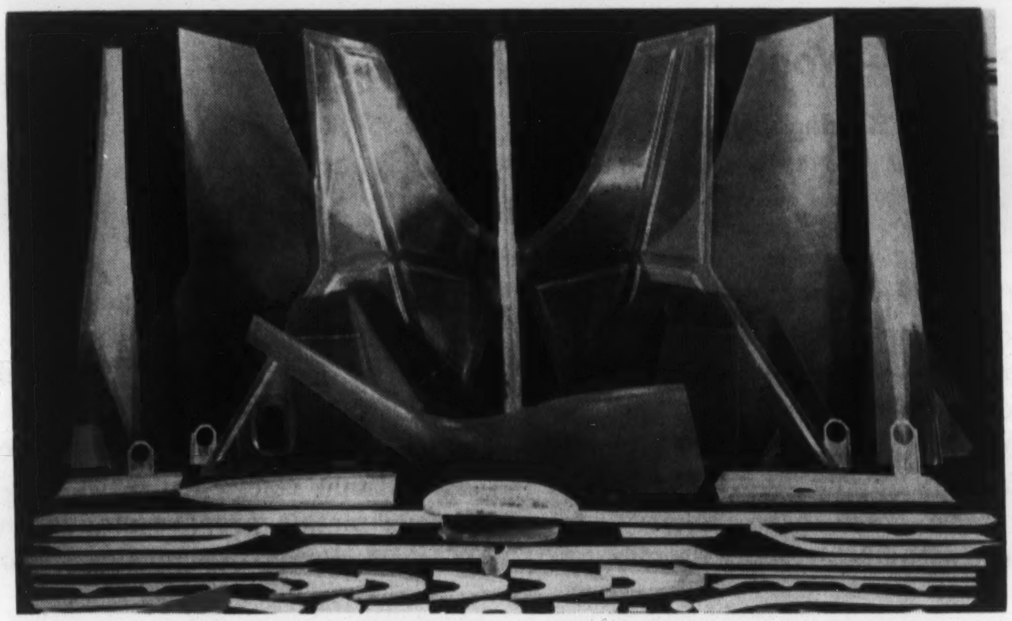
The pylon is a two-cell structure at the upper end, swelling to a three-cell structure at the lower end. The original design of the housing and pylon made use of detail parts such as spars and ribs of glass fabric-reinforced polyester laminates fabricated by the wet lay-up process. The pylon cover blankets were plastics honeycomb sandwich panels with glass fabric-reinforced polyester laminate skins manufactured by the same process. An aluminum beam was used in the area between the spars to stabilize the covers under load.

In the redesigned assembly, detail parts such as spars, ribs, doublers, frames and bulkheads are fabricated from type 181 glass cloth preimpregnated with polyester resin. The aluminum beam has been eliminated.

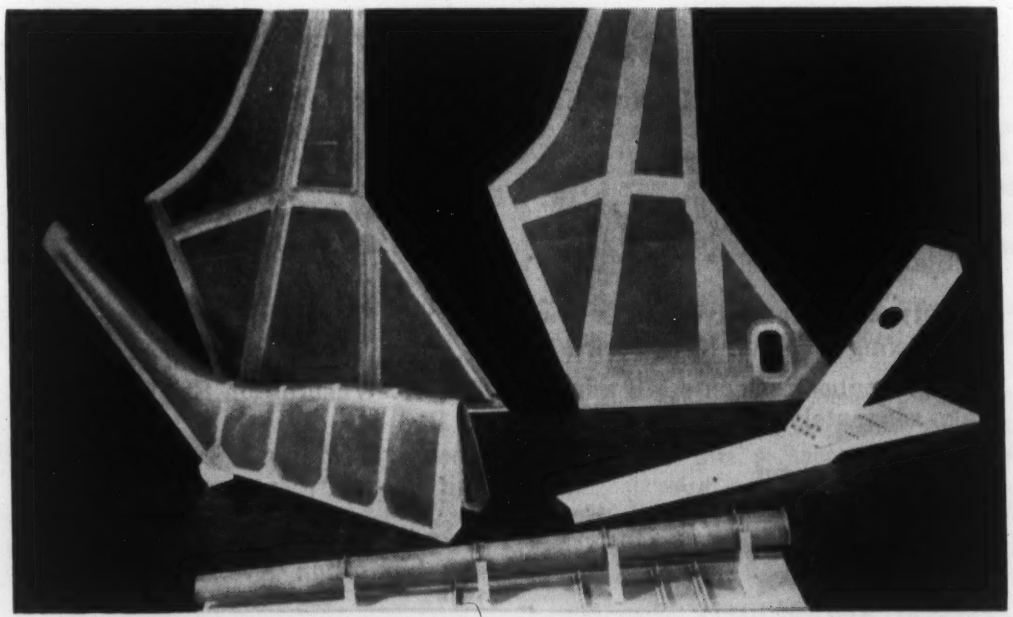
Use of prepreg materials has provided substantial cost reductions and an increase in production rate. Though the raw materials cost is 25% higher than before, this increase is more than offset by reduction in scrap and elimination of clean-up time and equipment, and in the economies inherent in procurement, handling, storage and inspection of only one material.

Unit cost of the redesigned housing and pylon is 55% lower than that of the original wet lay-up assembly. The original assembly required 872 man-hours as compared with 332 man-hours for the redesigned assembly. Also, reproducibility of quality is improved because of the controlled nature of the prepreg material.

The pylon

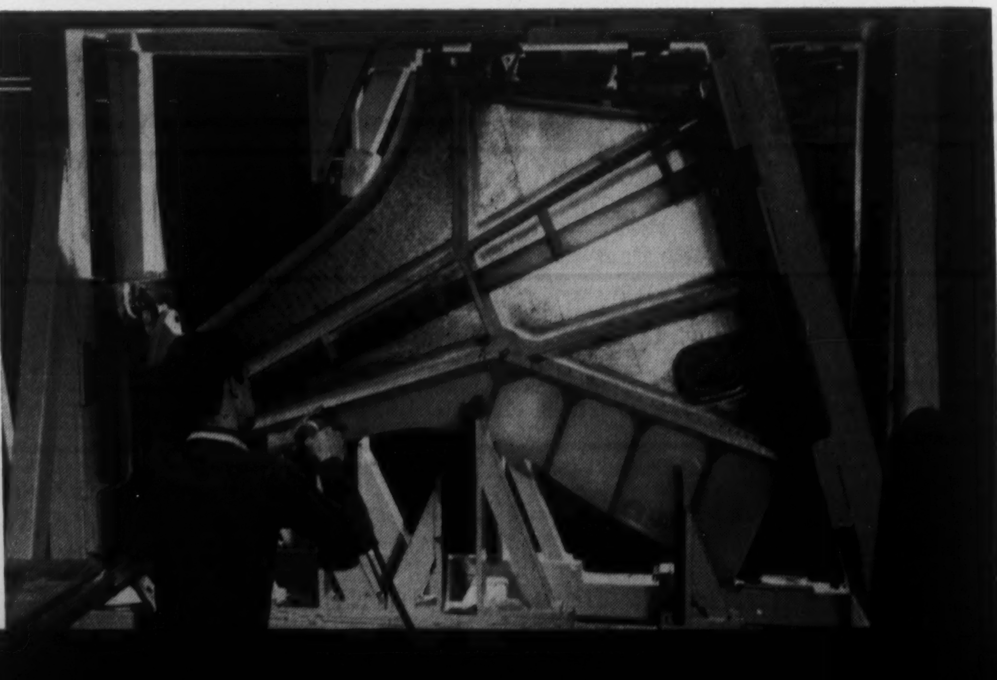


Components *are spars, ribs, leading edge and honeycomb core made from glass cloth-polyester prepreg. These are joined to make . . .*



. . . subassemblies *which are subsequently joined to form . . .*

. . . complete structure, *shown here in jig and with one side removed.*



Guide to Materials Standards and Specifications

Part 3—Nonferrous Metals

by S. P. Kaidanovsky,
Consulting Engineer

■ Standards and specifications on nonferrous metals and alloys are prepared or issued by most of the governmental agencies and national organizations, such as the Federal Supply Service, Dept. of Defense, American Society for Testing Materials, Society of Automotive Engineers and American Standards Assn. Their standardization activities were covered in Part 1 of this series.

In addition, a number of trade associations concerned with nonferrous metals prepare standards or assist standards agencies. Two of them, the Investment Casting Institute and the Metal Powder Assn., were covered in Part 2 of this series; the rest are covered here.

The standards and specifications on nonferrous metals issued by the various organizations are summarized in the table.

Aluminum Assn.

The Aluminum Assn. (AA) is the national trade association of the aluminum industry. For the purpose of promoting a better understanding between producer and consumer, the association has issued a standard glossary of terms for aluminum sheet, plate, and extruded and tubular products.

It has also developed and issued a standard alloy designation system for wrought aluminum. This system provides a four digit code for designation of wrought aluminum and wrought aluminum alloys, which is called an AA Number. The first digit of the designation indicates unalloyed aluminum, or major alloying element(s):

Unalloyed Aluminum (99.00% or better)	1XXX
Copper	2XXX
Manganese	3XXX
Silicon	4XXX
Magnesium	5XXX
Magnesium and Silicon	6XXX
Zinc	7XXX
Other Element	8XXX
Unused Series	9XXX

The second digit indicates impurity limits for unalloyed aluminum. or modification of original alloy. The last two digits indicate the aluminum purity for unalloyed aluminum, or identify the different alloys in the group.

If the second digit is zero, it indicates that there is *no special control* on individual impurities. Integers *1* through *9*, which are assigned consecutively as needed, indicate *special control* of one or more individual impurities.

In the *1XXX* group (aluminum of 99.00% min), the last two of the four digits indicate the minimum aluminum percentage to the

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Where to Obtain Standards for Nonferrous Metals

American Society for Testing Materials
1916 Race St., Philadelphia 3, Pa.
ASTM Standards, Part 2—Nonferrous Metals. Each standard available separately.[a]

Society of Automotive Engineers
485 Lexington Ave., New York 17.
SAE Handbook. Each AMS available separately.[a]

U. S. Government
Supt. of Documents, U. S. Government Printing Office, Washington 25, D. C.
Federal and Military Specifications. Each standard available separately.[a]

American Standards Assn.
70 E. 45th St., New York 17.
Each standard available separately.[a]

Investment Casting Institute
27 E. Monroe St., Chicago 3, Ill.
Investment Castings Specifications.

Metal Powder Assn.
130 W. 42nd St., New York 36.
Summary of Standards, Specifications for Metal Powders and Metal Powder Products.

Copper and Brass Research Assn.
420 Lexington Ave., New York 17, N. Y.
Manual of Standards.

Brass and Bronze Ingot Institute
300 W. Washington St., Chicago 6, Ill.
Technical Manual, Ingot Brass and Bronze.

Aluminum Assn.
420 Lexington Ave., New York 17.
The Aluminum Association Alloy Designation System. Glossary of Terms for Aluminum Sheet and Plate and Aluminum Extruded and Tubular Products.

American Die Casting Institute, Inc.
366 Madison Ave., New York 17.
Each standard available separately.

Dow Chemical Co.
Midland, Mich.
Magnesium Specifications Digest.

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[a] See first article (Mar '58) for information on index.
Use of standards issued by trade associations should not be considered mandatory.

This is the third in a series of six articles on materials standards and specifications. Subsequent articles will deal with organizations and standards on plastics and rubber, other nonmetallics and finishes.

nearest 0.01%. A 99.30% aluminum *without special control* of individual impurities would have: first digit, *1*, second digit, *0*, last two digits, *30*. Thus, the designation would be 1030. Aluminum of the same purity (99.30% min) *with special control* on *1, 2, 3*, etc., impurities would have the same first digit (*1*), but the second digit, instead of being *0*, would be *1, 2, 3*, etc., impurities. Thus, the designation of the aluminum would be *1130, 1230, 1330*, etc.

In the *2XXX* through *8XXX* alloy groups, the second digit in the alloy designation indicates alloy modifications. If the second digit is *0*, it indicates the original alloy; integers *1* through *9*, which are assigned consecutively, indicate alloy modifications. Thus, in the aluminum-copper alloy designation *2017*, the second digit, *0*, indicates the original alloy; in the designation *2117*, the second digit, *1*, indicates the modification of the original alloy.

The last two of the four digits in the designation of alloy groups have no special significance but serve only to identify the different alloys in the group. For new alloys the last two digits are assigned consecutively beginning with *XX01*.

The temper designation follows the alloy designation and is separated from it by a dash. The ASTM has developed a system for designating the tempers of light metals and alloys, both cast and wrought (B296-54T). The designations for temper are based on the sequence of basic treatments used to produce the temper.

Copper and Brass Research Assn.

The CABRA develops standards in tentative form through a representative committee of the copper industry. The tentatives are reviewed by the entire membership for comment or approval. The association publishes a Manual of Standards which gives considerable information on standards on wrought copper and copper-base alloys. These standards are called *Alloy Data*. Reference is made in these standards to the nearest

SUMMARY LIST OF STANDARDS AND SPECIFICATIONS FOR NONFERROUS METALS

Organization	Type of Document	Document Identification	Forms and/or Uses
ALUMINUM AND ALUMINUM ALLOYS			
ASTM	Spec	BXXX-Year	Ingots, forgings, bars, rods, wire; extruded bars, rods and shapes; pipe; drawn seamless, extruded tube; welding rods, bar electrodes; brazing filler metal
SAE	Std	—	Sheet, plate, drawn tube, extruded tube and shapes, rolled shapes, rods, bars, wire, rivets, forgings, forging stock
SAE	Mtl Spec	AMSXXX	Sheet, plate, foil; seamless, drawn hydraulic tubing; rolled or drawn bars, rods and wire; forgings, extrusions, brazing wire, welding rod and wire. Aeronautical uses
Federal	Spec	QQ-A-XXX	Plate, sheet; rolled or drawn bars, rods and wire; extruded bars, rods and shapes; free machining bars, rods and wire; forgings
Military	Spec	MIL-A-XXX	Forgings, plate, sheet, impact extrusions
ASTM	Spec	BXXX-Year	Sand, permanent mold and die castings
SAE	Std	—	Sand, permanent mold and die castings. Automotive and allied uses
SAE	Mtl Spec	AMSXXX	Sand, permanent mold, centrifugal, die and investment castings. Aeronautical uses
Federal	Spec	QQ-A-XXX	Sand, permanent and semi-permanent mold, and die castings
Military	Spec	MIL-A-XXX	Sand, permanent mold and die castings
ICI	Spec	AL-1	Alloy investment castings
ADCI	Std	ADCI-M2-55T	Die castings
ADCI	Std	ADCI-M3-55T	Die castings
COPPER AND COPPER ALLOYS			
ASTM	Spec	BXXX-Year	Wire, bars, slabs, billets, ingots, casting copper and copper for wrought products and alloys: plate, sheet, strip, rolled bars, rods, bars and shapes, die forgings, alloy wire, pipes and tubes; filler metal; sand, centrifugal and die castings
SAE	Std	—	Brass sheet and strip; aluminum bronze rods, bars, and shapes; copper sheet and strip, free-cutting brass rods; naval brass rods, bars, forgings and shapes; seamless brass tubes, copper tubes, phosphor bronze sheet and strip, brass wire, phosphor bronze wire and rod, annealed copper wire, brass forgings, sand castings
SAE	Mtl Spec	AMSXXX	Plate, sheet, strip, seamless tubing, rods, bars, forgings, wire, brazing wire, bearings; sand, centrifugal, investment and die castings. Aeronautical uses
SAE	Mtl Spec	AMSXXX	Leaded copper, leaded bronze, babbitt on bronze; bearings
Federal	Spec	QQ-C-XXX	Rods and shapes, flat wire, strip, bars, plate, rolled bars, sheet, strip, castings
Federal	Spec	QQ-B-XXX	Brass. Plate, bars, rolled bars, rods, sheet, strip, shapes, forgings, castings
Federal	Spec	QQ-B-XXX	Bronze rods, bars, rolled bars, shapes, forgings, plate, sheet, strip, castings
Federal	Spec	QQ-M-XXX	Manganese bronze. Bars, plate, rods, sheet, strip, flat wire, forgings, structural and special shaped sections, castings
Federal	Spec	QQ-N-XXX	Naval brass. Rods, bars, wire, shapes, forgings, flat products with finished edges
Federal	Spec	QQ-P-XXX	Phosphor bronze. Bars, plate, rods, sheet, strip, flat wire, structural and special shaped sections
Federal	Spec	QQ-L-XXX	Leaded tin bronze castings

applicable ASTM specifications. The association actively participates in the work of ASTM and ASA.

CABRA standard commercial wrought coppers and copper-base alloys are designated by descriptive names such as Low-Leaded Brass, Architectural Bronze, etc. In many cases, the percentage of copper and/or percentage of some of the alloying elements follows the name; e.g., Commercial Bronze, 90%; Red Brass, 85%; and Nickel Silver, 65-10. The date of latest issue is indicated on each document.

Brass and Bronze Ingot Institute

The BBII is active in establishing standards for ingot brass and bronze and castings. It actively cooperates in the ASTM's programs to standardize specifications for copper-base alloys in ingot form. For ten years the institute maintained a research associate at the National Bureau of Standards for the purpose of checking the practicality of such specifications.

The institute publishes a manual, *Ingot Brass and Bronze.* It includes information on ingot brass and bronze specifications, physical characteristics, uses and suggestions as to the techniques by which these alloys can be successfully and economically used.

The BBII specifications designate numerically each particular group of alloys, followed by a suffix letter *A, B, C,* etc., indicating the nominal composition of each alloy. Thus, leaded tin bronze with nominal composition 88 copper-6 tin-1½ lead-4½% zinc, is designated *2A.* Leaded tin bronze with nominal composition 87 copper-8 tin-1 lead-4% zinc is designated *2B.* The date of the latest issue is indicated on the document.

Lead Industries Assn.

The LIA does not issue its own standards or specifications. Usually when the association prepares a standard it attempts to have it promulgated by some nationally recognized standards organization or by the Federal Government.

SUMMARY LIST (continued) OF STANDARDS AND SPECIFICATIONS FOR NONFERROUS METALS

Organization	Type of Document	Document Identification	Forms and/or Uses
COPPER AND COPPER ALLOYS—continued			
Military	Spec	MIL-B-XXX	Bronze castings
Military	Spec	MIL-C-XXX	Castings
ASA	Spec	H-Year	Wire bars, slabs, billets, ingots, ingot bars; forging rods, bars and shapes; wire; free-cutting brass rods, bars and shapes
CABRA	Alloy Data	Number	Wrought products
BBII	Std	Number-Letter	Ingot brass and bronze alloys
ICI	Spec	CU-1	Silicon brass. Alloy investment castings
ADCI	Std	ADCI-M5-56T	Die castings
MAGNESIUM AND MAGNESIUM ALLOYS			
ASTM	Spec	BXXX-Year	Ingots, bars, rods, shapes, sheet, forgings, extruded tube, brazing filler metal
SAE	Std	—	Sheet, strip, bars, rods, shapes, tubing, forgings
SAE	Mtl Spec	AMSXXX	Extrusions, forgings, sheet, plate. Aeronautical uses
Federal	Spec	QQ-M-XXX	Bars, rods, special extruded sections, forgings, plate, and sheet
ASTM	Spec	BXXX-Year	Sand, permanent mold and die castings
SAE	Mtl Spec	AMSXXX	Sand, permanent mold and die castings. Aeronautical uses
SAE	Std	—	Sand, die and permanent mold castings. General application
Federal	Spec	QQ-M-XXX	Sand, permanent and semi-permanent mold, and die castings
ICI	Spec	MG-1	Alloy investment castings
ADCI	Std	ADCI-M7-56T	Die castings
NICKEL AND NICKEL ALLOYS, COBALT ALLOYS			
ASTM	Spec	BXXX-Year	Plate, sheet, strip, rods, bars, wire, pipe, tubing, filler metal
Federal	Spec	QQ-N-XXX	Bars, plate, rods, sheet, strip, wire, forgings, structural and special shaped sections
Military	Spec	MIL-N-XXX	Bars, forgings
ASA	Spec	H-Year	Seamless pipe and tubing
Federal	Spec	QQ-N-XXX	Castings. General use
ICI	Spec	NI-1	Alloy investment castings
ICI	Spec	CO-1	Cobalt-base alloys. Investment castings

The association cooperates with all the standardizing organizations by supplying them with information and reviewing the specifications for technical and commercial acceptability. The LIA is represented on many ASTM committees, and it works closely with the Federal Supply Service, General Services Administration on Federal Specifications, and with the Commodity Standards Div. of the Dept. of Commerce.

Magnesium Assn.

The Magnesium Assn. does not develop standards or specifications of its own. Its members use those issued by the various specification writing organizations. To assist the designers and users of wrought magnesium and magnesium castings, the Magnesium Dept. of the Dow Chemical Co. publishes a Magnesium Specifications Digest listing Federal, MIL, SAE, AMS and ASTM specifications. A brief digest and an interpretation of each specification is given.

American Zinc Institute

The AZI's effort for development of standards and specifications is conducted by committees or task groups, but it does not issue specifications of its own.

SUMMARY LIST (concluded) OF STANDARDS AND SPECIFICATIONS FOR NONFERROUS METALS

Organization	Type of Document	Document Identification	Forms and/or Uses
LEAD- AND TIN-BASE ALLOYS			
Military	Spec	MIL-T-XXX	Tin. Strip, sheet
Federal	Spec	QQ-T-XXX	Tin (phosphor). General use
Federal	Spec	QQ-T-XXX	Tin alloy ingots and castings; lead alloy ingots and castings (antifriction metal). Bearing uses
ASTM	Spec	BXXX-Year	Lead- and tin-base alloy die castings
TITANIUM AND TITANIUM ALLOYS			
ASTM	Spec	BXXX-Year	Strip, sheet, plate, bars, tube, rods, wire
SAE	Mtl Spec	AMSXXX	Plate, sheet, strip, bars, forgings, welded tubing. Aeronautical uses
ZINC AND ZINC ALLOYS			
ASTM	Spec	BXXX-Year	Slab, rolled
Federal	Spec	QQ-Z-XXX	Plate, sheet, strip
ASA	Spec	H-Year	Slab (spelter), rolled
ASTM	Spec	BXXX-Year	Die castings, ingots for die castings
SAE	Genl Info	—	Die castings
Federal	Spec	QQ-Z-XXX	Die castings
Military	Spec	MIL-Z-XXX	Sand castings
ADCI	Std	ADCI-M9-57T	Die castings
NONFERROUS METAL POWDERS			
ASTM	Spec	BXXX-Year	Bronze, brass, copper-infiltrated iron. Structural parts
SAE	Genl Info	—	Bearings, structural parts, filters. Automotive and general industrial uses
Military	Spec	MIL-B-XXX	Oil-impregnated. Bearings. Aircraft uses
Military	Spec	JAN-A-XXX	Aluminum powder
Military	Spec	MIL-B-XXX	Brass. Structural parts
Military	Spec	JAN-M-XXX	Magnesium, magnesium-aluminum
Military	Spec	JAN-M-XXX	Manganese
Military	Spec	JAN-N-XXX	Nickel. Parts
Military	Spec	JAN-T-XXX	Tin. Parts
Military	Spec	MIL-Z-XXX	Zirconium-nickel, zirconium. Parts
MPA	Specs Summary	DS	Parts, bearings

Most of the specifications of interest to the institute are developed and issued by Government agencies and recognized standards organizations. Representatives of the AZI are committee members of such organizations or work closely with them in formulating and modifying specifications on zinc and zinc alloys.

American Die Casting Institute

The ADCI is an association of job shop producers of die castings. To assist users of die castings, the institute prepares a series of guides called Product Standards for Die Castings. They are: *Engineering Products Standards, Metallurgical Standards* and *Commercial Practices.* The Metallurgical Standards, in particular, cover the composition, properties and characteristics of aluminum, copper, magnesium and zinc-base alloy die castings.

Engineering Product Standards are numbered serially and bear the prefix *E*. Metallurgical Standards are also numbered serially and bear the prefix *M*. Each standard is identified as ADCI. In addition the designation consists of the last two digits of the year in which the standard is adopted or revised, and a suffix *T* if the standard is Tentative. Thus, Metallurgical Standard, Zinc-Base Alloy Die Castings is designated ADCI-M9-57T.

ASTM Designations

The American Society for Testing Materials has developed a system for designating cast and wrought light metals and alloys which they use in their standards for aluminum, magnesium and zinc (Recommended Practice B275-55).

In this system the full name of the base metal precedes the designation, but is omitted for brevity when the base metal being referred to is obvious.

Designations for alloys consist of not more than two letters representing the alloying elements specified in greatest amount, arranged in order of decreasing percentages. If the elements occur in equal percentages, the arrangement is in alphabetical order. These letters are followed by the respective percentages rounded off to whole numbers. Finally, a serial letter is arbitrarily assigned, in alphabetical sequence, to differentiate between designations that would otherwise be identical.

Below are the letters assigned to the various alloying elements.

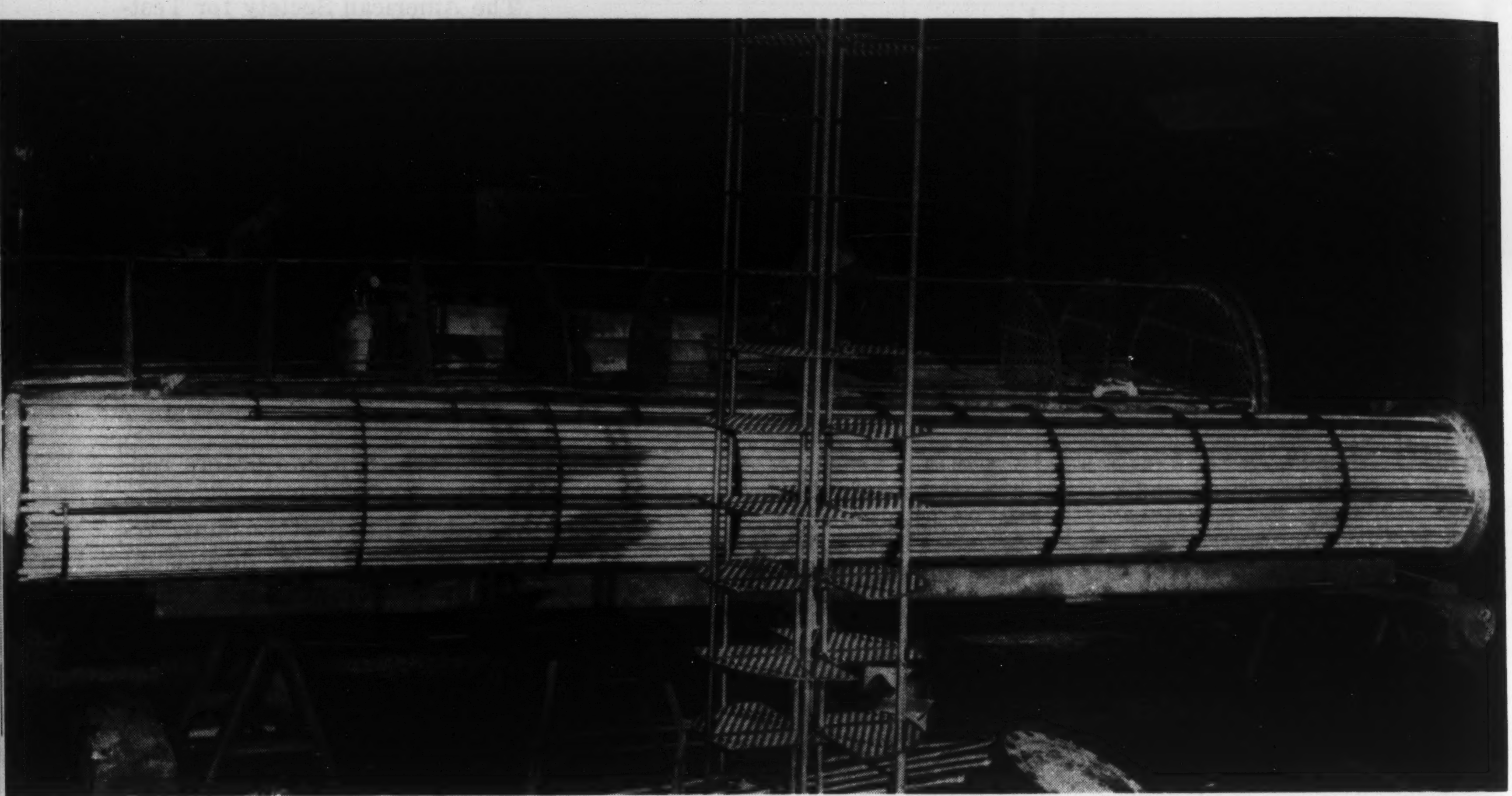
A—Aluminum
B—Bismuth
C—Copper
D—Cadmium
E—Rare Earths
F—Iron
G—Magnesium
H—Thorium
K—Zirconium
L—Beryllium
M—Manganese
N—Nickel
P—Lead
Q—Silver
R—Chromium
S—Silicon
T—Tin
Y—Antimony
Z—Zinc

For example, ZG61A is an aluminum alloy containing 6% zinc and 1% magnesium and is the first of a series of such alloys.

The ASTM also has developed standard designations for coppers (B224-52). The designation consists of a group of two to four capital letters which, in general, are the initial letters of the descriptive name of the coppers. For example, electrolytic tough pitch copper is ETP.

Cupro-Nickels Offer

Cupro-nickel tubing is used for . . .



American Brass Co.

Fuel oil cooler *in a petroleum refiner—here being re-tubed with Cupro-Nickel, 30% tubes.*

Main condenser *of a steam power plant—a 45,000-sq ft unit composed of Cupro-Nickel, 10% tubes.*

American Brass Co.

Corrosion Resistance and Hot Strength

Here is a comprehensive report on the properties, fabrication and uses of an important group of copper alloys.

by J. L. Everhart, *Technical Editor, Materials in Design Engineering*

■ The cupro-nickels have been used for many years in marine service but the increased availability of nickel is reviving and stimulating interest in the application of these alloys to other fields. Composed essentially of copper and nickel, the group of commercial alloys ranges in nickel content from 2.5% to 30%; the alloys containing 30% and 10% nickel are most widely used.

The outstanding attributes of the cupro-nickels are corrosion resistance, particularly their resistance to the corrosive and erosive effects of high velocity sea water, and strength at elevated temperatures. They are widely used in applications requiring exceptional corrosion resistance such as heat exchanger, condenser or evaporator service involving salt solutions. They are also used in applications involving contact with food products.

Wrought alloys

Although essentially simple copper-nickel alloys, the commercial wrought alloys actually contain minor quantities of other elements. Of these, the most important is iron which has been found to increase the resistance of the cupro-nickels to corrosion and erosion by salt water. In the 30% alloy (30% nickel), iron content is held to 0.7% max. In the 10% alloy, addition of about 1.3% iron improves resistance to salt water.

Composition and properties

TABLE 1–Wrought

Commercial Designation ➡	Cupro-Nickel, 30%	Cupro-Nickel, 20%	Cupro-Nickel, 10%
Nearest ASTM Specifications ➡	B111-57, B122-55T, B171-55	B111-57, B122-55T	B111-57, B171-55
NOMINAL COMPOSITION, %	Cu 68.9, Ni 30, Fe 0.5, Mn 0.6	Cu Bal, Ni 21, Fe 0.5, Mn 0.6	Cu 88.35, Ni 10, Fe 1.25, Mn 0.4
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.323	0.323	0.323
Melting Range, F	2260-2140	2190-2100	2080-2020
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	17	21	26
Coef of Ther Exp (68-572 F), per °F	9.0×10^{-6}	9.1×10^{-6}	9.3×10^{-6}
Specific Heat, Btu/lb/°F	0.09	0.09	0.09
Elec Resistivity (68 F), microhm-cm	37	27	15
Modulus of Elasticity in Tension, psi	22×10^6	20×10^6	18×10^6
Modulus of Rigidity, psi	8.3×10^6	7.5×10^6	6.8×10^6
MECHANICAL PROPERTIES			
Tensile Strength, 1000 psi			
Annealed Strip[a]	54-60	45-51	44
Half Hard Strip	73	—	—
Hard Strip	80	—	—
Annealed Tube[a]	54-60	49	44
Light Drawn Tube	75	80	60
Yield Strength (0.5% ext), 1000 psi			
Annealed Strip[a]	20-22	—	15
Half Hard Strip	68	—	—
Hard Strip	73	—	—
Annealed Tube[a]	25	14	16
Light Drawn Tube	—	75	57
Elongation (2 in.), %			
Annealed Strip[a]	40-45	27	40
Half Hard Strip	12	—	—
Hard Strip	5	—	—
Annealed Tube[a]	45	40	42
Rockwell Hardness			
Annealed Strip[a]	B37-50	—	B10
Half Hard Strip	B80	—	—
Hard Strip	B85	—	—
Annealed Tube[a]	B36-45	B25	B15
Light Drawn Tube	B85	B81	B72

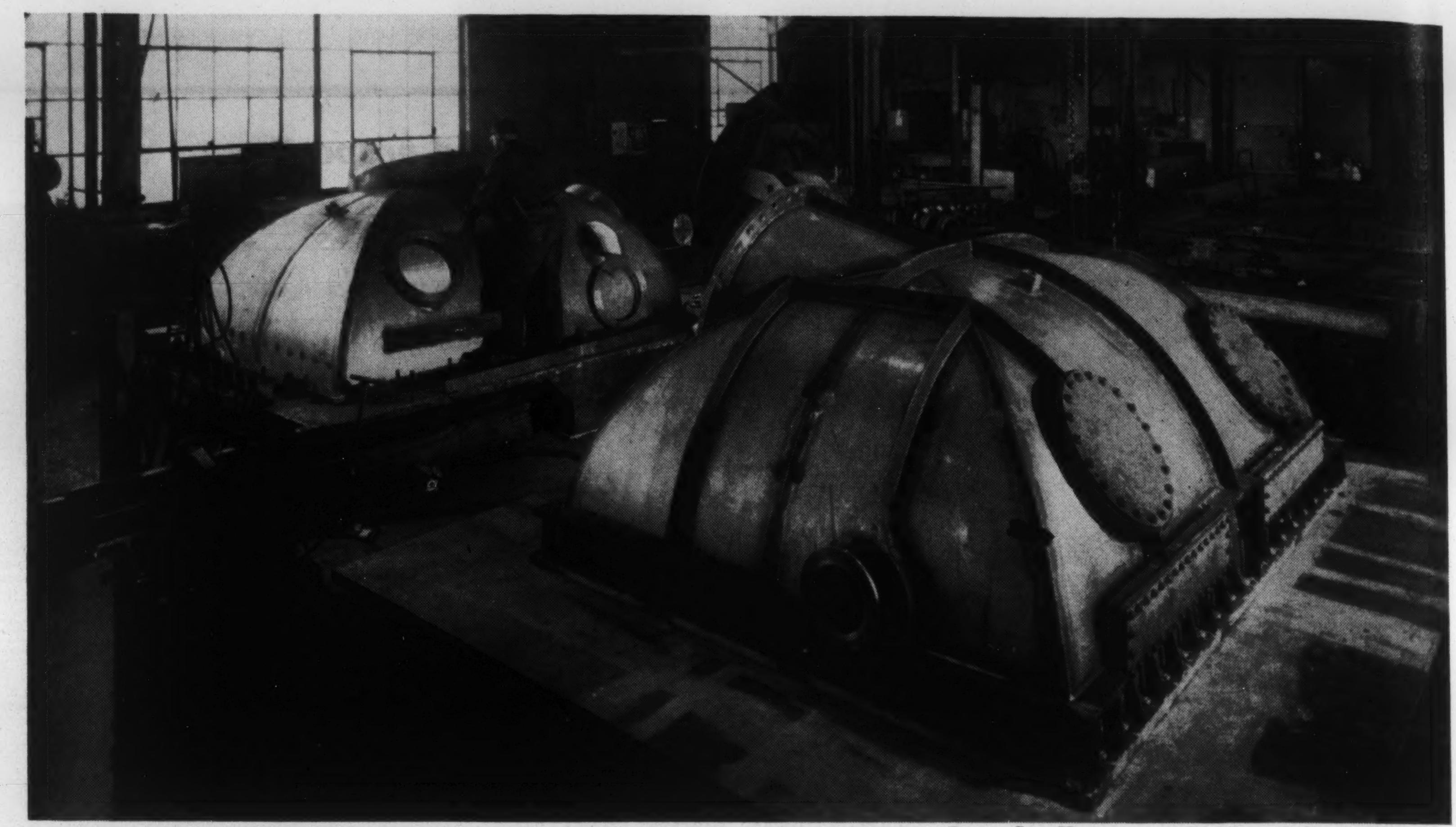
[a] Properties of annealed materials vary with grain size.

TABLE 2–Cast

Commercial Designation ➡	70-30	80-20	90-10
NOMINAL COMPOSITION, %	Ni 30, C 0.10, Mn 0.90, Si 0.50, Fe 1.0, Cu bal	Ni 20, C 0.10, Mn 0.90, Si 0.50, Fe 1.0, Cu bal	Ni 10, C 0.10, Mn 1.20, Si 0.10, Fe 1.0, Cu bal
MECHANICAL PROPERTIES (as cast)			
Tensile Strength, psi	65,000	60,000	45,000
Yield Strength, psi	30,000	25,000	20,000
Elongation (in 2 in.), %	20	20	25
Brinell Hardness	—	—	90

Source: *Vanick.*

Cupro-nickel sheet is used for . . .

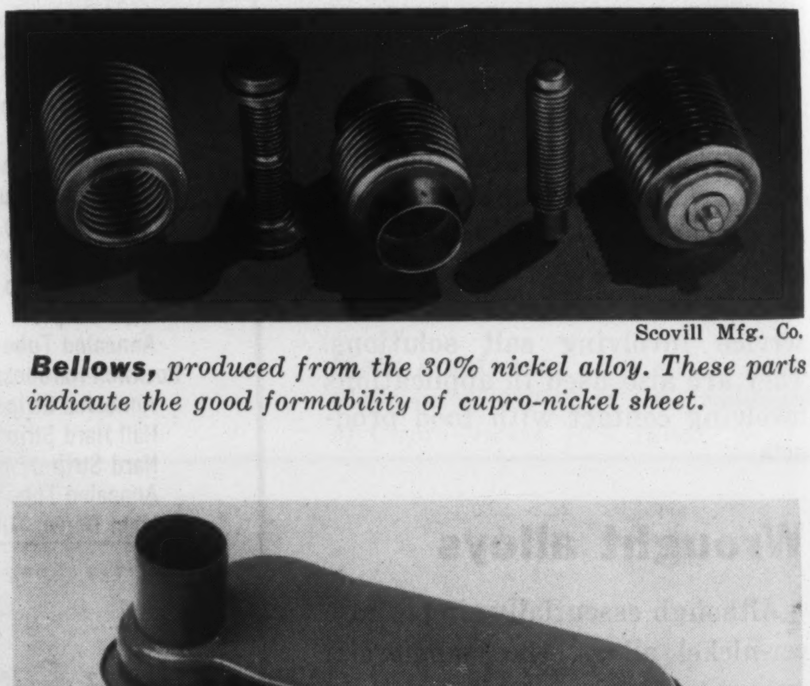


American Brass Co., Youngstown Welding & Engineering Co.

Water boxes *for the main condenser of an aircraft carrier, fabricated by welding ¼-in. sheet of Cupro-Nickel, 10%. Ribs and flanges are steel.*

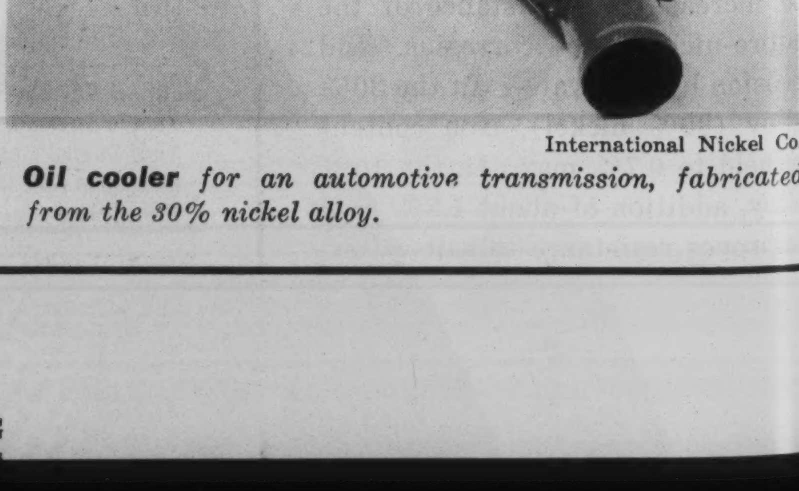
Copper & Brass Research Assn.

Suction pipe *for a Navy transport, fabricated by welding formed segments of Cupro-Nickel, 10% sheet.*



Scovill Mfg. Co.

Bellows, *produced from the 30% nickel alloy. These parts indicate the good formability of cupro-nickel sheet.*



International Nickel Co.

Oil cooler *for an automotive transmission, fabricated from the 30% nickel alloy.*

Since copper and nickel are mutually soluble in each other, there is a gradual change in many of the physical properties of the alloys with increasing nickel content. As shown in Table 1, melting point and modulus of elasticity increase and thermal and electrical conductivities decrease.

Mechanical properties are affected similarly. Hardness and tensile and yield strengths of the 30% alloy are higher than those of the 10% alloy. Ductility, as measured by elongation, is also higher in the 30% alloy.

Subnormal temperatures have no embrittling effect on the standard wrought cupro-nickels. As shown in Table 3 (p 117), strength and ductility increase with falling temperature down to at least -320 F.

At elevated temperatures, the 30% grade in the annealed condition retains much of its short-time strength and ductility up to about 700 F. Above this temperature, both decrease rather rapidly. Cold drawn material (see graph) also retains its strength to about the same temperature. With increasing temperature, however, the strengthening resulting from cold work is gradually lost and, at 1200 F, cold drawn material has the same properties as annealed material.

The creep properties of wrought cupro-nickels are among the highest obtained in copper alloys. Table 4 gives representative creep strengths at several temperatures.

Cast alloys

Since it is impractical to harden castings by cold working, hardening elements such as iron, carbon, silicon, manganese, aluminum and tin are included in the composition of cast alloys. (Some of these elements cannot be used in wrought alloys.) Iron, carbon, silicon and manganese are considered essential in the cast alloys; aluminum and tin are employed for special purposes. Compositions and typical mechanical properties of the usual cast grades are given in Table 2. The limited data avail-

Effect of temperature

TABLE 3—Low temperature

Alloy	Temp, F	Yld Str (0.2% ext), 1000 psi	Ten Str, 1000 psi	Elong (2 in.), %	Red. of Area, %	Izod Impact Value, ft-lb
70-30 (annealed)[a]	Room	21.5	54.1	37	27	—
	−108	24.0	64.3	42	30	—
	−220	27.4	71.9	47	32	—
	−320	30.9	83.7	52	34	—
80-20 (annealed)[b]	Room	27.7[c]	51.5	26	78	77
	−110	28.9[c]	61.6	29	76	79
	−170	29.2[c]	66.1	28	75	84
	−290	32.5[c]	73.7	36	72	85

[a] Source: *Jenkins, Digges and Johnson.* [b] Source: *Colbeck and MacGillivray.*
[c] 0.1% permanent set.

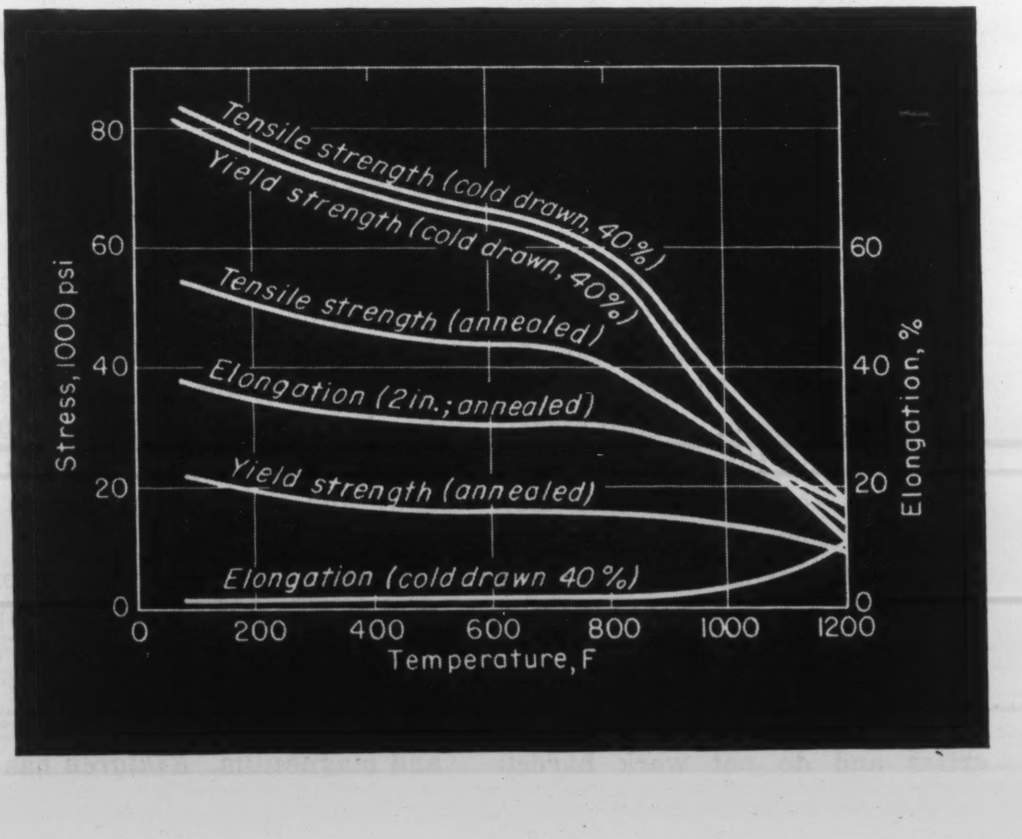
TABLE 4—Creep

Alloy ⇩	Temper	Temp, F	Stress for Designated Creep Rate, 1000 psi 0.001%	 0.01%	 0.1%
			Strain Per 1000 Hr		
70-30	Annealed (0.020 mm grain size)	300	24.0	35.0	—
		500	16.0	30.0	—
80-20	Annealed (0.025 mm grain size)	300	> 25.0	—	—
		500	17.0	> 30.0	—
90-10[a]	Annealed (0.025 mm grain size)	300	> 30.0	—	—
		400	16.0	30.0	—
		500	11.0	24.5	—
90-10	Cold Drawn (21%)	300	37.8	> 50.0	—
		400	25.6	42.5	46.0
		500	16.7	28.5	36.0

[a] Containing 1.08% iron.
Source: *Port and Blank.*

Short-time high temperature

Cupro-Nickel, 30%. *(Jenkins, Digges and Johnson).*



able show that these grades have low and high temperature properties similar to those of the corresponding wrought alloys.

Cupro-nickels alloyed with 2 to 10% tin are hard and corrosion resistant. These grades are heat treatable; considerable increase in hardness can be achieved by quenching from a relatively high temperature (1450 to 1650 F) and aging at about 700 F. Aluminum can be added to cupro-nickels to increase the tensile and yield strengths, although careful foundry control is necessary to obtain satisfactory results. For example, an alloy containing 12% nickel and 1.5% aluminum, with normal iron, silicon and manganese contents, has tensile strength in the range 85,000 to 95,000 psi, yield strength 60,000 to 70,000 psi, and elongation 7 to 13%.

Corrosion resistance

Since copper and nickel are soluble in all proportions, the cupro-nickel alloys have a single phase structure and are not subject to the selective attack that sometimes occurs in alloys having more than one phase. Iron, normally present in commercial alloys, is within the solid solution range after commercial annealing and does not promote localized attack.

Cupro-Nickel, 30% is outstanding in its resistance to general and impingement attack by clean sea water; at low water velocities it is subject to biofouling, but this effect can be avoided by using higher velocities. The iron content of the 10% alloy makes it almost as resistant as the 30% alloy to sea water. The alloys also have excellent resistance to attack by fresh water, boiler feed water and steam.

The cupro-nickels are resistant to attack by sulfuric acid, phosphoric acid and the mild organic acids. They are attacked by nitric acid, chromic acid, hydrochloric acid and hydrobromic acid.

In many environments, rate of corrosive attack depends upon composition. *LaQue* has illustrated this effect with caustic soda. Nickel is much superior to copper in resistance to attack by strong alkalis; as would be expected, therefore, increasing the nickel content of copper alloys reduces the rate of attack. For example, tests have shown that the rate of attack by 50% caustic soda on Cupro-Nickel, 10% is roughly twice that on Cupro-Nickel, 30%. Cupro-nickel has been used successfully in evaporator tubes for concentrating caustic soda to about 50% in applications where copper pick-up by the caustic was not detrimental to the product. Although the cupro-nickels can be used with higher concentrations, they are attacked quite severely by fused caustic.

According to *LaQue*, the cupro-nickels are superior to other copper alloys in resistance to ammonia and ammoniacal compounds. They are said to have been used advantageously in handling steam contaminated with low concentrations of ammonia in evaporators, and for handling ammoniacal solutions in other equipment.

These alloys are resistant to the alkaline chlorides, sulfates, nitrates and chromates, but are attacked by the cyanides and acid dichromates. They resist attack by ferrous sulfate and chloride, but are attacked by the corresponding ferric salts.

Cupro-nickels are resistant to wet and dry chlorine, bromine and carbon dioxide, and to dry hydrogen sulfide at ordinary temperatures. They are attacked by moist hydrogen sulfide. At elevated temperatures, the alloys are subject to rapid corrosion by hydrogen sulfide and other sulfur compounds.

As in all work involving corrosion, these remarks should be considered only as a qualitative evaluation of the alloys under discussion. Before selecting an alloy for a specific service, tests should be made under service conditions.

Fabricating characteristics

Here is a brief summary of the processing characteristics of the cupro-nickels (see also Table 5).

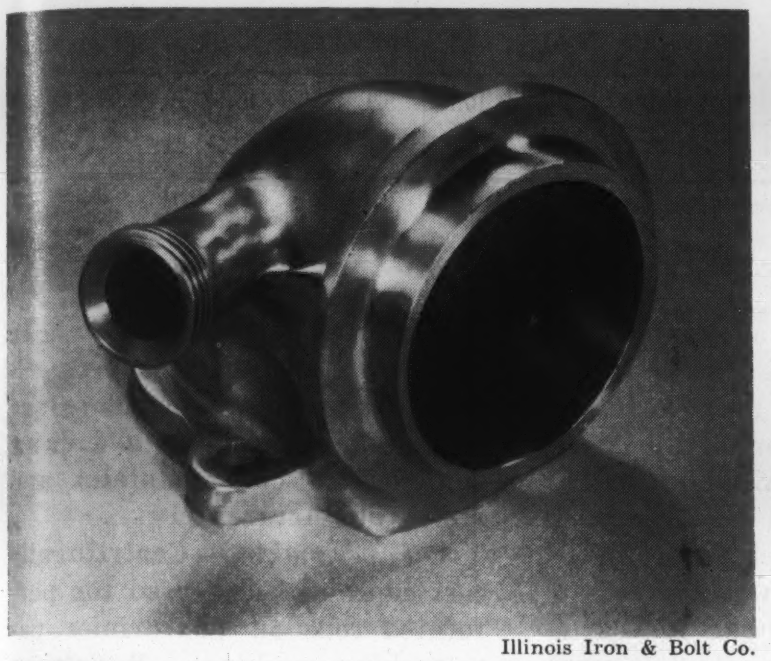
Hot working—The hot working characteristics of cupro-nickels are good, and they can be rolled, extruded, formed or bent hot. However, their flowing qualities are rather poor and the alloys are not usually recommended for forging.

Cold working—The cupro-nickels have excellent cold working properties and do not work harden rapidly. They are suitable for the production of parts by deep drawing, stamping and spinning. These alloys can be annealed in the temperature range 1100 to 1500 F, the temperature depending on the alloy and the final properties desired.

Casting — Production of pressure-tight castings from cupro-nickel requires melting under oxidizing conditions followed by deoxidation with silicon, manganese and magnesium. *Kihlgren* has described the melting practice in detail. A pouring temperature as high as 2650 F can be used for thin wall castings. Pouring temperature must be at least as high as 2575 F for moderate to heavy sections; a temperature as low as 2500 F has been used for heavy castings.

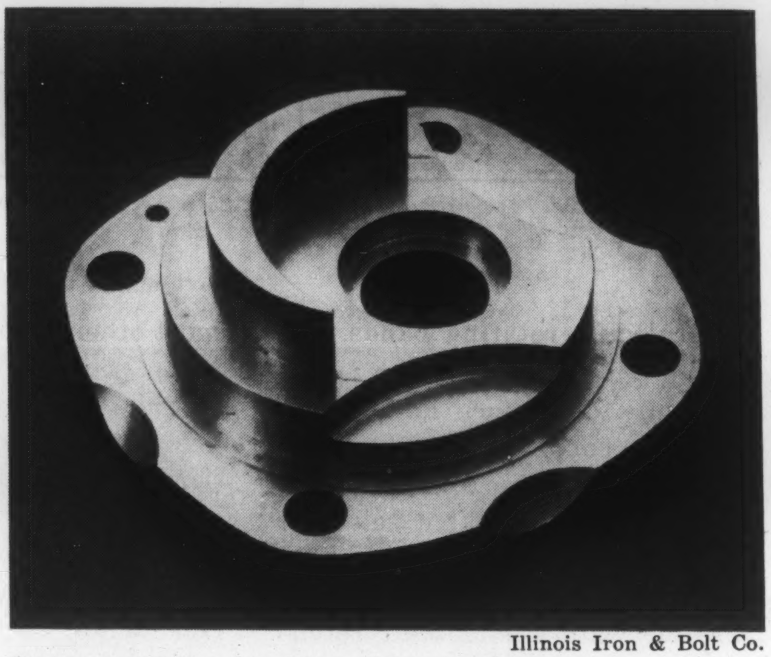
Machining — The relative machinability of copper alloys is indicated by comparison with free-cutting brass, the most readily machinable of the copper alloys.

Cupro-nickel castings are used for . . .



Illinois Iron & Bolt Co.

Fittings *for an ice cream manufacturing machine.*



Illinois Iron & Bolt Co.

Pump part *for handling dairy products.*

Based on an arbitrary rating of 100 for free-cutting brass, the cupro-nickels containing up to 30% nickel have a machinability rating of 20 and are classed as difficult to machine. Tools, coolants and speeds used in machining the non-leaded coppers are satisfactory for machining cupro-nickel.

Joining—The cupro-nickel alloys can be welded, brazed and soldered. Some indication of the suitability of the various processes can be obtained from Table 5.

TABLE 5—FABRICATING PROPERTIES

Alloy ➡	Cupro-Nickel, 30%	Cupro-Nickel, 20%	Cupro-Nickel, 10%
Cold Workability	Good	Good	Good
Hot Workability	Good	Good	Good
Hot Working Temperature Range, F	1700-1900	1650-1850	1550-1750
Annealing Temperature, F	1200-1500	1200-1500	1100-1500
Machinability Rating (free-cutting brass = 100)	20	20	20
Joining Characteristics			
Soft Soldering	Excellent	Excellent	Excellent
Silver Alloy Brazing	Excellent	Excellent	Excellent
Oxyacetylene Welding	Fair	Fair	Fair
Carbon Arc Welding	Not recommended	Not recommended	Not recommended
Gas Shielded Arc Welding	Excellent	Excellent	Excellent
Metal Arc Welding	Excellent	Excellent	Good
Resistance Welding	Excellent	Excellent	Good

In welding with the inert-gas tungsten-arc process or the inert-gas metal-arc process, the shielding gas can be either helium or argon. The filler metal must be of the same analysis as the base metal. The cupro-nickels can also be welded by the various resistance processes. Since the oxides of these alloys are refractory, the surfaces must be carefully cleaned before welding. Gas welding procedures for the cupro-nickels are similar to those used in welding monel.

Brazing can be done successfully with standard silver alloy filler metals. A suitable flux is required to limit formation of nickel oxide. Stress relieving is desirable for brazed assemblies.

The cupro-nickels can be soldered with the standard grades of solder. Generally 50 lead-50% tin solder serves for work to be used at moderate temperatures, and 95 tin-5% antimony for the higher temperatures. Acid fluxes give the best results.

Applications

Cupro-Nickel, 30% is the most widely used of this group of materials. However, Cupro-Nickel, 10% which was developed to conserve nickel is more economical and can be used for many applications. The 20% alloy has properties intermediate between these two; however, improvement over the 10% alloy is not sufficient to justify the additional cost, and service too severe for the 10% alloy generally requires use of the 30% grade. The 2.5% nickel grade is a special alloy used only

TABLE 6—MAXIMUM ALLOWABLE DESIGN STRESSES FOR SEAMLESS TUBING

Alloy	Condition	Maximum Stress, 1000 psi, for Metal Temperatures Not Exceeding Those Indicated (F)												
		100	150	200	250	300	350	400	450	500	550	600	650	700
Cupro-Nickel, 30%.......	Annealed.......	12.0	11.6	11.3	11.0	10.8	10.6	10.3	10.1	9.9	9.8	9.6	9.5	9.4
Cupro-Nickel, 20%.......	Annealed.......	10.7	10.6	10.5	10.4	10.3	10.1	9.9	9.6	9.3	8.9	8.4	7.7	7.0
Cupro-Nickel, 10%.......	Annealed.......	10.0	10.0	9.8	9.5	9.3	9.0	8.7	8.3	7.5	6.7	6.0	—	—

Source: *ASME Boiler and Pressure Vessel Code:* Section VIII, Unfired Pressure Vessels.

for projectile rotating bands.

Tubing

Tubing for service in heat exchangers, condensers and evaporators is the major application of the cupro-nickels, their selection being based on resistance to corrosion and erosion, particularly in saline waters, and their retention of strength at elevated temperatures. The cupro-nickels are suitable for the highest water velocities normally encountered in exhaust condensers.

Although the cupro-nickels have only about one-third the thermal conductivity of Admiralty, under operating conditions both have practically the same effective heat transfer. (Thermal resistance of the tube walls accounts for only a small part of the temperature head necessary for flow of heat from vapor on one side to the cooling water on the other.) However, 10% additional surface is sometimes provided by designers as a safety factor in using cupro-nickel in place of Admiralty.

The 70-30 alloy is widely used for tubes, tube sheets and baffles in main condensers for fast turbine-operated ships such as naval vessels and ocean liners. The 90-10 alloy is employed in auxiliary condensers on ships.

Corrosion in evaporators is usually more of a problem in the vapor than in the liquid phase. Frequently there are traces of ammonia in steam plant vapors. Since the cupro-nickels are more resistant to low concentrations of ammonia than other copper alloys, they are frequently selected for evaporator service.

As mentioned previously, the cupro-nickels retain their strength up to higher temperatures than most other copper alloys, and their creep rate is also lower. This thermal stability permits higher design stresses for elevated temperature service and is often the deciding factor in selecting these alloys. For example, cupro-nickel was selected as the tubing material in an evaporator for chemically treated water used as steam plant feed because of the requirement that the 1-in. o.d., 18 BWG tubes operate at 700 F and a design pressure of 150 psi.

In the petroleum industry, the 30% nickel alloy is used for heat exchangers and condensers in handling process liquors, vapors and cooling water that are corrosive and at temperatures too high for other copper alloys. The 10% alloy is used for similar service in handling sulfur-free liquids in a number of tidewater refineries in which brackish water is used as the coolant.

A different kind of application in which the corrosion resistance of cupro-nickel is useful is the tubes in an absorption refrigerating machine that uses low pressure steam to chill water for air conditioning and process cooling.

Other uses

1. Marine service—In addition to their use in condensers, the cupro-nickels are used in many other marine applications because of their excellent resistance to sea water corrosion. Included are salt water lines, pumps, valves and valve seats, rudder parts, propeller shaft sleeves and trim. Although marine condenser water boxes are usually cast, the Navy fabricates them from sheet metal to save weight.

2. Food processing—The good corrosion and abrasion resistance of the cupro-nickels lead to use in food processing plants for juice extractors, shredders, mixers, filters and presses. The alloys are also used in creamery and dairy equipment, soda fountain and restaurant fixtures.

3. Paper making—Centrifugally cast cupro-nickel is used for perforated rolls on Fourdrinier papermaking machines. Resistance to corrosion is about the same as that of the phosphor bronze usually used but the cupro-nickel has the advantage of additional stiffness resulting from its higher modulus of elasticity.

4. The cupro-nickels are also used in the production of bolts, bellows, industrial pickle baskets, ferrules and coin blanks. The U.S. five cent piece, commonly called the nickel, is made of a cupro-nickel alloy.

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Acknowledgments

The assistance of the following organizations in preparing this article is gratefully acknowledged.

American Brass Co.
Bridgeport Brass Co.
Chase Brass & Copper Co.
Copper & Brass Research Assn.
Illinois Iron & Bolt Co.
International Nickel Co.
Revere Copper and Brass, Inc.
Riverside Metal Div., H. K. Porter Co.
Scovill Mfg. Co.

Materials
in Design Engineering

Manual No. 148
May 1958

New Developments in Ceramics

by **John H. Koenig,** *Director, School of Ceramics, Rutgers University*

Coors Porcelain Co.

Engineered ceramic parts like these . . .

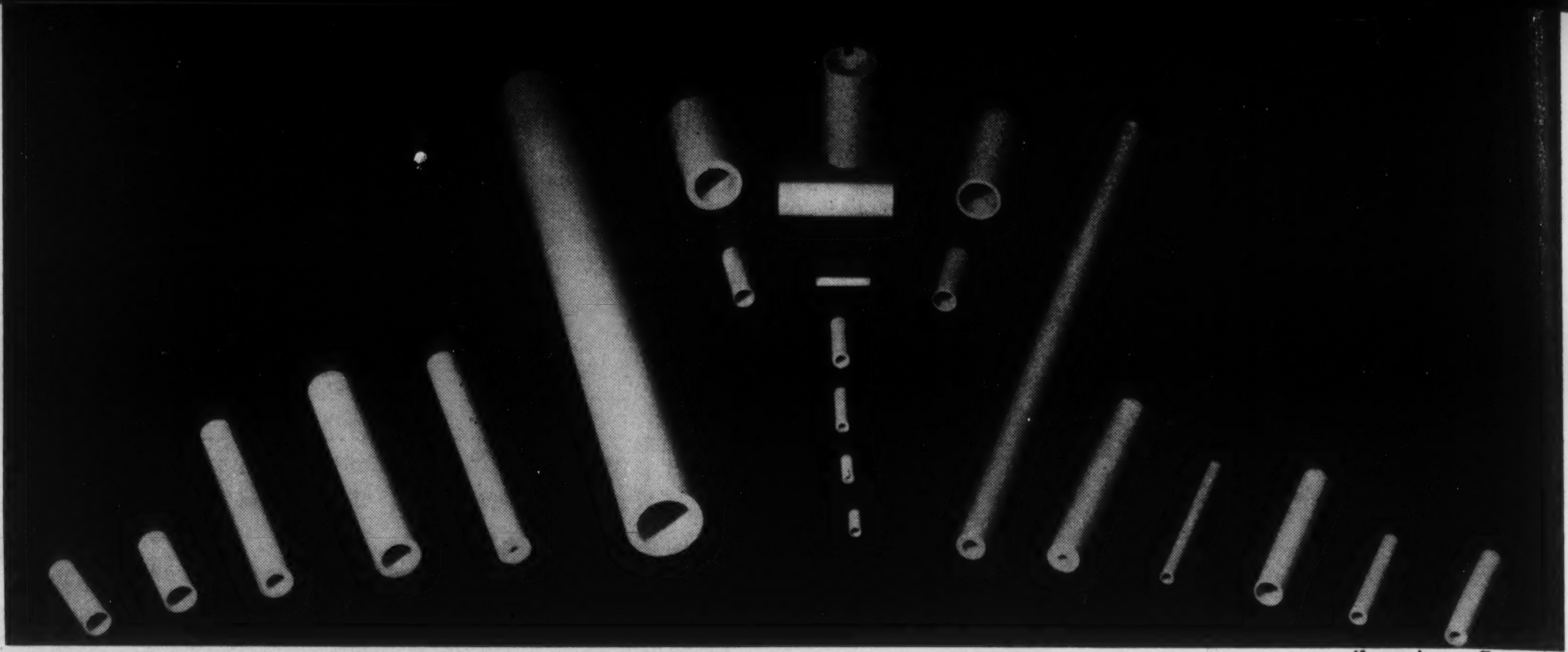
. . . are more important today than ever before. Here is a survey of the entire field of ceramics giving detailed information on properties, state of development, and new uses of these new and improved materials:

Electrical ceramics
- *Electrical insulating materials*
- *Ferromagnetics*
- *Ferroelectrics*
- *Semiconductors*

Mechanical ceramics
- *Alumina*
- *Polycrystalline glass*

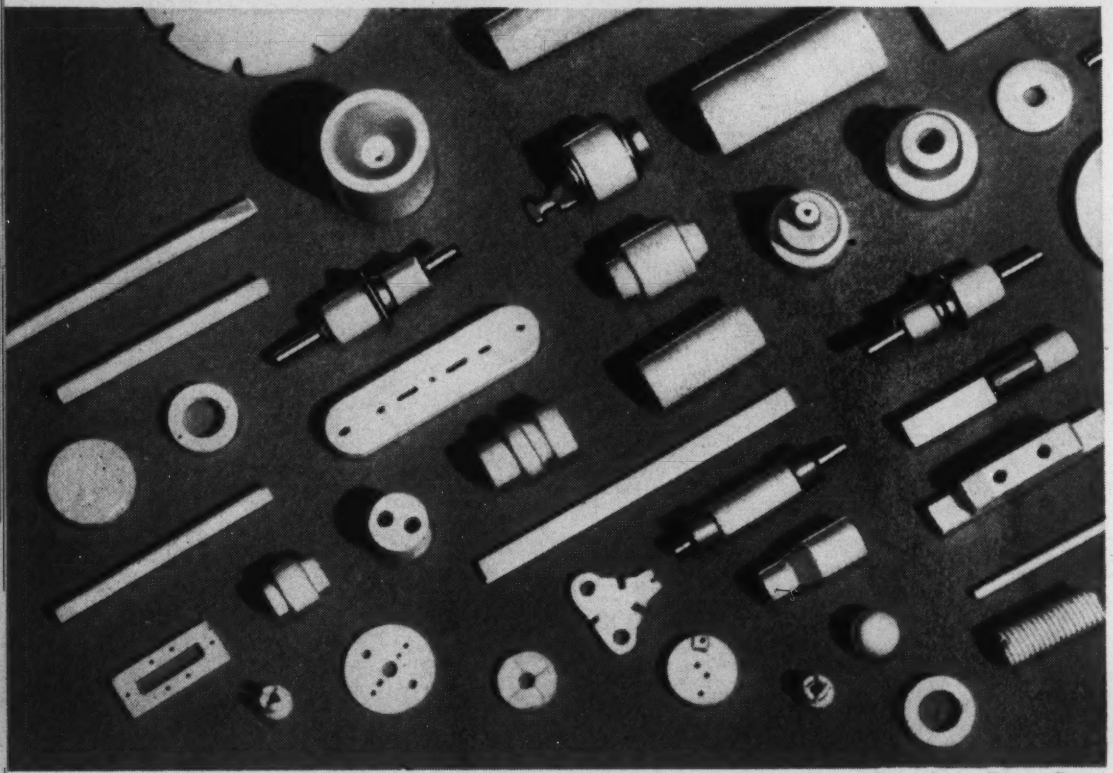
High temperature ceramics and cermets
- *Oxides*
- *Borides*
- *Silicides*
- *Carbides*
- *Nitrides*
- *Aluminides*

Nuclear ceramics
- *Fuels*
- *Moderators*
- *Shielding materials*
- *Structural materials*

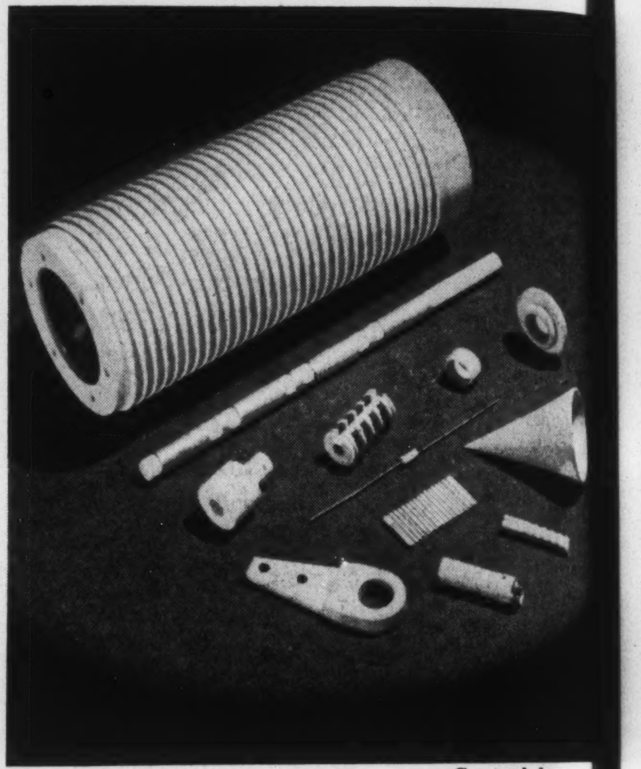


Saxonburg Ceramics

Steatite, *still the most widely used low loss, high frequency ceramic, is used for such things as resistor cores, capacitor sleeves, and thermocouple ball and socket beads.*



American Lava Corp.



Centralab

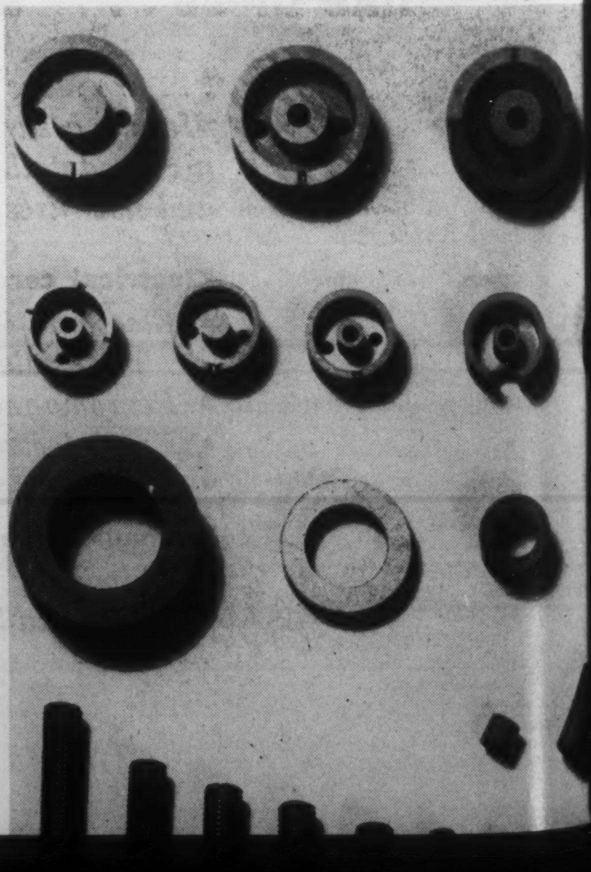
Alumina *parts, shown with ceramic-metal seals, are being used in an increasing number of electrical applications.*

Barium titanates *of various compositions are the most important piezoelectric materials for use in transducers.*

Gulton Industries, Inc.

Ferrite *materials are used for a variety of core applications.*

General Ceramics Corp.



1. Ceramics for electrical and electronic uses

Many of the older so-called "classical" ceramics such as electrical porcelains, though they are still widely used for electrical insulation, will not be discussed here. The majority of the new developments in electrical ceramics lie in specialized fields of use.

Electrical insulating ceramics

Table 1 shows typical properties of some of the more important ceramic insulating materials other than electrical porcelains. Steatite (principal phase is $MgO \cdot SiO_2$) continues to be the most widely used high frequency ceramic insulating material. It has excellent mechanical properties and can be fabricated readily to close tolerances; relatively poor thermal shock resistance limits its use somewhat. Forsterite ($2MgO \cdot SiO_2$) has lower loss factors at high frequencies than steatite, but it also has poor thermal shock resistance. Dense cordierite ($2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$) has good thermal shock resistance, but relatively poor dielectric properties. Porous cordierite bodies are used primarily as refractories.

Zircon ($ZrO_2 \cdot SiO_2$) has relatively good thermal shock resistance and good physical properties, but is difficult to fabricate because of its high hardness. Magnesia (MgO), though it has a high melting point and good dielectric properties, is difficult to fabricate. Single crystal quartz (SiO_2) and very pure fused silica (quartz glass) have very low loss factors, but size limitations and impurity problems present drawbacks to volume use at present.

High alumina (Al_2O_3) ceramics have extremely good dielectric characteristics at both high and low frequencies and high and low temperatures. They also have excellent mechanical properties and stability at elevated temperatures. From their early use as spark plug insulators they have continually grown in importance and are used in an increasing number of electrical and electronic applications. Alumina ceramics are discussed in more detail in the section on Ceramics for Mechanical Applications (see p 127).

New materials with novel properties—The lowest loss ceramic developed to date is a lead-fluxed wollastonite ($CaO \cdot SiO_2$) type material which is vitrified to zero water absorption at 2150 F. It has dielectric characteristics better than those of Grade L-6 ceramics (see Table 2).

Near zero or negative thermal expansion characteristics can be provided by several ceramic compositions in the lithia-alumina-silica system. Compositional boundaries of the materials possessing this characteristic are 3 to 16% lithia, 10 to 52% alumina and 38 to 82% silica. A zero or near zero coefficient (over a temperature range of 77 to 1100 F) can be obtained in certain compositions to provide excellent thermal shock resistance.

Some ceramic materials can provide relatively high expansion characteristics, such as forsterite (5.8×10^{-6}), magnesia (7.1×10^{-6}), and lithium titanate (10.8×10^{-6}). These materials provide these expansivities over the temperature range of 77 to 1290 F. Though such high coefficients provide very poor thermal shock resistance, they are useful in applications such as in compression seals.

Although most ceramics have low thermal conductivity (below 5 Btu/hr/sq ft/°F/ft at 140 F), materials are now available with conductivity values similar to those of metals. As compared with values for aluminum and copper of 118 and 218 Btu/hr/sq ft/°F/ft, respectively, dense, high beryllia (BeO) ceramics provide conductivity values ranging from 125 to 28.5, depending on the type and amount of flux used. Dense high magnesia bodies have values

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Scope of This Manual

The last manual on ceramics ("Ceramics for Engineering Applications," MATERIALS & METHODS, Sept '50) covered the older, so-called "classical" ceramic materials. This manual outlines the most important recent developments in ceramic materials. Because of the extensive nature of these developments and the space limitations of this manual, only the most important materials developments are covered in detail. In some cases, however, brevity can be attributed to the newness of the materials and the consequent lack of further information.

Recent developments in ceramic materials have been primarily aimed at extending the property ranges of the materials to meet new design requirements. Improvements attained to date have been accomplished mainly by 1) modification of the constituents and improvements in the quality of existing ceramic materials, and 2) development of entirely new materials.

The first approach is probably best exemplified by improvements in alumina-type ceramic materials. These improvements, taking the form of closer control over quality and particle size of raw materials and closer control over processing, have accounted for many of the newer uses of alumina ceramics. The new materials approach to extending the design possibilities of ceramics is exemplified by such developments as polycrystalline glasses, intermetallic semiconducting compounds, and the new refractory ceramics.

This manual is organized by the general type of end service for which each type of ceramic is best suited. Of course, many ceramics are suitable for more than one type of service; in these cases references in each pertinent section indicate where the material is discussed in further detail.

Properties of some electrical ceramics

TABLE 1—TYPICAL PROPERTIES OF SOME CERAMIC INSULATING MATERIALS

Grade[a] ➡	Steatite ($MgO \cdot SiO_2$) L5A	Forsterite ($2MgO \cdot SiO_2$) L6B	Dense Cordierite ($2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$) L2A	Zircon ($ZrO_2 \cdot SiO_2$) L4A
PHYSICAL PROPERTIES				
Water Absorption, %	0-0.02	0-0.02	0-0.02	0-0.02
Specific Gravity	2.65	2.90	2.65	3.68
Softening Temperature, F	2600	2600	—	2800
Max Cont Svc Temp, F	1800	1800	2200	2100
Coef of Ther Exp, per °F				
77-390 F	4.2×10^{-6}	—	1.8×10^{-6}	2.2×10^{-6}
77-750 F	4.4×10^{-6}	5.8×10^{-6}	2.1×10^{-6}	2.4×10^{-6}
77-1100 F	4.6×10^{-6}	5.9×10^{-6}	2.3×10^{-6}	2.6×10^{-6}
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	1.69	1.94	2.42	3.15
MECHANICAL PROPERTIES				
Flexural Strength, psi	20,000	20,000	18,500	26,000
Tensile Strength, psi	10,000	10,000	9,500	12,000
Compressive Strength, psi	85,000	85,000	90,000	95,000
Impact Strength (Charpy), in.-lb	4.6	4.0	4.4	5.6
ELECTRICAL PROPERTIES				
Dielectric Strength, v/mil	240	240	230	230
Dielectric Constant				
1 Mc	6.1	6.2	6.2	8.8
100 Mc	6.0	6.1	—	8.6
Power Factor				
1 Mc	0.0013	0.0004	0.0093	0.0010
100 Mc	0.0010	0.0003	—	0.0012
Loss Factor				
1 Mc	0.007	0.002	0.0579	0.009
100 Mc	0.005	0.002	—	0.010
Te Value, F	1500	>1832	—	1590

[a] MIL Spec JAN-I-10.

TABLE 2—CLASS L CERAMICS
(MIL Spec JAN-1-10)

Grade	Loss Factor
L-1	0.150
L-2	0.070
L-3	0.035
L-4	0.016
L-5	0.008
L-6	0.004

ranging from 22.4 to 14.0. Dense pure oxide ceramics, in order of decreasing thermal conductivity, rate as follows: BeO, MgO, stannic oxide (SnO_2), zinc oxide (ZnO), alumina, cupric oxide (CuO), thoria (ThO_2), ceria (CeO_2), calcia (CaO), titania (TiO_2) and lead oxide (PbO).

Two types of ceramics possess zero shrinkage, which greatly simplifies fabrication to accurate dimensions. These are 1) a lead bisilicate-fluxed spodumene ($Li_2O \cdot Al_2O_3 \cdot 4SiO_2$), and 2) a crystalline lead alumino-silicate, which is a Grade L-5 material with a self-glazing mechanism. The glaze, which forms during firing, is highly resistant to water and thus provides high resistivity under extremely humid conditions.

Recently a family of polycrystalline glass materials called Pyroceram has been developed. The materials have excellent dielectric characteristics; high frequency characteristics of one type (Code 9605) are reportedly comparable to those of the best electrical ceramics. The materials can be formed by any of the conventional glass forming techniques, and they have high strength-to-weight characteristics. The materials are discussed in detail in the section on Ceramics for Mechanical Applications, and properties are given in Table 7 (p 130).

Ferromagnetic ceramics

The term "ferrite" has been used to describe a variety of iron oxide compounds which are ferromagnetic spinels. When an electrical field is applied to these materials a magnetic response is obtained.

A number of new ferromagnetic ceramics have been developed with unique magnetic properties and high internal resistance. The combination of high permeability with low loss in these materials can not be had in other materials.

Most of the early development work involved "soft" ferrite systems such as $MnO\text{-}ZnO\text{-}Fe_2O_3$, $NiO\text{-}ZnO\text{-}Fe_2O_3$ and $NiO\text{-}CuO\text{-}ZnO\text{-}Fe_2O_3$. Such ferrites have been used in radio antennas, filter and adjustable inductors, deflection yokes, recording heads and wide band transformers. Magnetic properties of several proprietary ferrites are shown in Table 3.

Ferrites are made from ferric oxides and varying amounts of one or more bivalent metallic oxides, hydroxides or carbonates, such as those formed with zinc, manganese, nickel, cobalt, magnesium and copper. The spinel-type ferrite develops its structure by solid state reaction during firing. Organic additives are frequently used to assist in fabrication. Particle size distribution, forming pressures and shrinkage characteristics affect properties of the ferrite. Firing is probably the most critical operation in obtain-

TABLE 3—MAGNETIC PROPERTIES OF SOME COMMERCIAL FERROMAGNETIC CERAMICS[a]

	Soft Ferrites					Rectangular Loop Ferrites	
	H	H-1	0-1	0-2	Q	S-4	S-5
Initial Permeability (1 mc/sec)	850	550	800	1100	125	38	43
Max Permeability[b]	4300	3800	4250	3100	400	920	2600
Saturation Flux Density (B_s), gauss[b]	3400	2800	4250	4500	3300	1860	2100
Residual Magnetism, gauss[b]	1470	1500	1600	1600	1800	—	—
Coercive Force, oersted[b]	0.18	0.35	0.24	0.30	2.1	1.3	0.64
Temp Coef of Initial Perm, %/°F	0.37	0.44	0.33	0.33	0.06 max	—	—
Curie Point, F	300	255	375	375	660	—	—
Volume Resistivity, ohm-cm	Medium	Medium	Low	Low	High	—	—
Loss Factor ($1/M_oQ$)							
1 mcs/sec	0.00030	0.0004	—	—	0.000020	—	—
5 mcs/sec	0.00155	0.0010	0.000015[c]	0.000011[c]	0.000050	—	—
Retentivity (B_r), gauss	—	—	—	—	—	1630	1950
B_r/B_s	—	—	—	—	—	0.88	0.93

[a] Materials are proprietary—trademarked Ferramic.
[b] Measurements made on d.c. ballistic galvanometer; $H_{max} = 25$ oersteds for soft materials; $H_{max} = 5$ oersteds for rectangular loop materials.
[c] At 50 kc per sec.
Source: General Ceramics Corp.

TABLE 4—REPRESENTATIVE SEMICONDUCTORS—PROPERTIES AND APPLICATIONS

Material	Band Separation (at 300 K), ev	Mobility (at 300 K), cm/v-sec		Melting Point, F	Application
		Electrons	Holes		
Germanium (Ge)	0.72	3600	1900	1708	Rectifiers, transistors
Gallium Antimonide (GaSb)	0.6[b]	3000[b]	1000[b]	1295	
Silicon (Si)	1.12	∽ 2000	∽ 500	2588	High temperature rectifiers and transistors; solar batteries; infrared optics; photocells
Indium Phosphide (InP)	1.27	4000[b]	650	1922	
Gallium Arsenide (GaAs)	1.34	5000[b]	300	2262	
Cadmium Telluride (CdTe)	1.45	∽ 1000	100[b]	1913	
Aluminum Antimonide (AlSb)	1.6	400[b]	400	1922	
Cadmium Sulfide (CdS)[a]	2.4	250[b]	—	—	
Gold-Doped Ge[a]	0.72	3600	1900	1716	Infrared detectors; filters
Mercury Telluride (HgTe)[a]	∽ 0.06	∽ 17,000	—	1238	
Indium Antimonide (InSb)	0.16	75,000	800	972	Magnetoresistance devices; Hall effect devices; thermistors
Indium Arsenide (InAs)	0.33	40,000	600[b]	1727	
Lead Telluride (PbTe)	0.3	2000	1100	1688	Infrared detectors
Lead Selenide (PbSe)	0.26	1200	600	1976	
Lead Sulfide (PbS)	0.4	800	400	2048	
Bismuth Telluride (Bi_2Te_3)[a]	0.16	570[b]	400[b]	1076	Thermoelectric devices
Cadmium Antimonide (CdSb)[a]	0.5	—	400[b]	852	

[a] One compound of a family of two or more related compounds.
[b] Minimum value.
Source: Willardson, R. K., and Shilliday, T. S., "The New Semiconductor Materials," Materials in Design Engineering, Mar '58, p 114.

ing desired properties; careful control over the time-temperature cycle is mandatory.

Rectangular loop ferrites—Ferrite materials with square or rectangular hysteresis loops have been developed more recently. Rectangular loop ferrites have two stable states of magnetization. Table 3 shows magnetic properties of two such commercial ferrites. Square or rectangular hysteresis loops with sharply marked corners can be produced with certain compositions of the MgO-MnO-Fe_2O_3 system. The best compositional range in this latter system seems to be between 40 and 45% (molecular) iron oxide; with these limits on the iron oxide the other components can be varied considerably.

Rectangular loop ferrites are used as storage cells in magnetic memory systems, and in a number of other applications, including switching, and automatic controls for processing and production equipment. Memory elements produced from these ferrites are generally very small toroids. A newer concept in memory devices consists of the use of a ferrite plate in which small holes have been drilled. The drilled plate replaces the conventional core-type construction.

Microwave ferrites—One of the most recent developments in ferroelectric ceramics is the microwave ferrite. In such bodies the critical properties are the Faraday rotation effect and the ferromagnetic resonance absorption. These materials are useful wherever carrier waves are in the microwave frequency range. They provide flexible methods of controlling rf energy and nonreciprocal components.

Permanent magnet ferrites—Ceramic permanent magnets have a hexagonal rather than a spinel structure; however, they are similar to ferromagnetic spinels in properties. They also are called ferrites. The barium ferrites ($BaO \cdot 6Fe_2O_3$) and lead ferrites ($Pb \cdot 6Fe_2O_3$) are probably the most prominent commercially. A cermet of cobalt-bonded cobalt oxide is said to provide a true permanent magnet.

The hard or permanent barium ferrite is made from a precalcined mixture of barium carbonate ($BaCO_3$) and iron oxide (Fe_2O_3), which is milled to a controlled particle size distribution with crystallites as near domain size as possible. It is then fired in an oxidizing atmosphere.

Ferroelectric ceramics

A ferroelectric material is one that exhibits a spontaneous electric dipole moment. (Ferroelectricity, in general, is the analogue of ferromagnetism; thus the prefix "ferro".) Though high dielectric constants (one of the major indications of ferroelectric behavior in a material) have been available in a number of ceramic titanates, some of the new ferroelectrical materials now available have increased stability at high temperatures.

The most important of the ferroelectric ceramics are barium titanate ($BaO \cdot TiO_2$), lead titanate ($PbO \cdot TiO_2$), strontium titanate ($SrO \cdot TiO_2$), lead niobate ($2PbO \cdot Nb_2O_5$) and combinations of lead zirconate ($PbO \cdot ZrO_2$) and lead titanate. Barium titanate, in combination with other titanates, zirconates, stannates and titania, are supplied industrially as disks, tubes and sheets for capacitors.

Ferroelectric ceramics are used mainly for capacitors and transducers. Two types of capacitors are produced from this type of ceramic: the T.C. (temperature compensating) type and the G.M.V. (guaranteed minimum value) type.

The T.C. type is used singly or in combination in circuits to compensate for temperature-caused variations in such characteristics as resistance, inductance and tube output. It is supplied with negative, zero or positive temperature coefficients of capacitance. The negative and zero types have dielectric constants in the range of 15 to 40. The positive temperature coefficient type is supplied with temperature coefficients ranging from just above zero to several thousand parts per million per °F in the 50 to 230 F temperature range.

The G.M.V. type is used principally as a by-pass capacitor. As the name implies, it guarantees a given minimum value of capacitance over a specified temperature range. It is supplied commercially with dielectric constants up to 10,000.

Ferroelectric ceramics with narrow hysteresis loops are also used in dielectric amplifiers, frequency doublers, variable filters, modulators, and temperature controls and indicators. Ferroelectrics with square hysteresis loops are used in memory elements in high speed electronic computers and in some types of automatic control devices.

Antiferroelectric ceramics—Antiferroelectric ceramics are materials in which, though they are spontaneously polarized, the neighboring lines of ions are polarized in antiparallel directions, resulting in a net dipole moment of zero. The most important antiferroelectric ceramics are lead zirconate and some combinations of lead zirconate and lead titanate. These antiferroelectrics can also be made ferroelectric over a narrow temperature range below the Curie temperature.

Piezoelectric ceramics—All ferroelectric ceramics are piezoelectric, i.e., they can transform mechanical energy to electrical energy and vice versa. When a potential is applied to such a material it will increase in size along certain axes and contract along others, depending on the polarization axis. Conversely, when a mechanical stress is applied to the material an electric potential is produced. This characteristic disappears at temperatures above the Curie temperature of the material, since at such temperatures the material is neither ferroelectric nor piezoelectric.

Barium titanate is the principal ceramic piezoelectric. However, it is limited to relatively low temperature service since its Curie temperature is 250 F. Where higher temperature service is to be encountered several lead oxide-base ceramics can be used. They are stable, provide uniform responses over a wider temperature range than barium titanate, and have excellent mechanical properties. A typical composition is a 45 lead titanate-55% lead zirconate which has a Curie temperature of about 645 F. It has a voltage coefficient more than twice that of barium titanate, but its piezoelectric charge output coefficient is comparable.

The high voltage coefficient makes the lead titanate-lead zirconate particularly useful for applications requiring conversion of mechanical stress to electrical energy. The addition of lead and tin oxides to this composition, on the other hand, provides very high piezoelectric charge output coefficients. Such a material is particularly useful in applications requiring conversion of electrical energy to mechanical stress, e.g., drivers in ultrasonic devices.

Piezoelectric ceramics are widely used in accelerometers, phonograph pickups, microphones, ultrasonic grinding and cleaning devices, and underwater signalling equipment.

Semiconducting ceramics

A variety of combinations of properties is available in ceramic semiconductors. The conventional types, finding use in all types of electronic equipment, have low temperature coefficients, low voltage coefficients and normal dissipation capacities. Other types have combinations of low (positive) to high (negative) temperature coefficients, nearly zero to extremely high voltage coefficients, and normal to exceptional dissipation capabilities.

Silicon carbide is probably the most widely used ceramic semiconductor, its principal use being as a heat source. Heating elements made of silicon carbide have been used in resistance type furnaces and kilns operating at temperatures up to 2800 F. Such elements conduct electricity at room as well as elevated temperatures.

Sintered mixtures of metallic oxides such as manganese, cobalt, nickel, iron and copper, when vitrified, are used as semiconductors in thermistors for electromechanical instrumentation and electronic circuitry. These materials generally have a high negative temperature coefficient of resistance (i.e., resistivity varies inversely with temperature), and are extremely sensitive to temperature changes. Thermistors made from these materials are of several types, depending on the application. They may be supplied uncoated or coated with organic material for service at temperatures up to 300 F; or they may be glass coated and mounted in evacuated or gas filled envelopes for service up to 930 F.

Thermistor materials with large positive temperature coefficients have been developed recently. In general they consist of barium titanate or barium strontium titanate, to which small amounts of lanthanum have been added. Bismuth, thorium and rare earths are also used as additive materials. One such material is reported to have a positive temperature coefficient over a temperature range of about –58 to 230 F, the coefficient being as high as 5% per °F. Another composition has a maximum positive temperature coefficient of 8% per °F from about 120 to 490 F.

Thermistors for use at extremely high temperatures (1000 to 2000 F) are said to be producible from a variety of compositions in the potassium alumino-silicate system. Certain alkali alumino-silicates maintain their resistivity-temperature calibration at temperatures up to 1800 F and are unaffected by oxidizing or reducing atmospheres.

New intermetallic semiconductors—Many intermetallic semiconducting compounds are now being studied and seem to hold great promise. Table 4 lists representative materials of this type with their properties and potential applications. Silicon and germanium metals are listed for purpose of comparison.

Only three of the materials listed are available commercially in this country. They are: bismuth telluride, indium antimonide and lead telluride. The rest are to be found only in research laboratories or on special order from companies which use the materials in their own production.

In addition to use in heat sensitive resistance elements such as thermistors, these compounds are expected to find use in 1) rectifiers and transistors operable at high temperatures, 2) galvanomagnetic devices such as computer elements, electronic compasses, amplifiers and microphones, 3) optical devices such as infrared detection systems and solar batteries, and 4) thermoelectric devices for power generation or refrigeration.

2. Ceramics for mechanical applications

Ceramic materials used for mechanical applications under high temperature conditions are discussed in the section on Ceramics for High Temperature Use (p 131). The substantial improvements in mechanical properties of ceramics at room temperature have resulted in many new applications where heat resistance is not a primary consideration. Probably the materials of most commercial interest are alumina and polycrystalline glasses. Since most of the newer applications for cermets involve high temperature service they are discussed only in the section on Ceramics for High Temperature Uses.

The following sections summarize the most important developments in 1) improving mechanical properties of ceramics, 2) newer materials, and 3) some of the newer areas of applications.

Improved properties

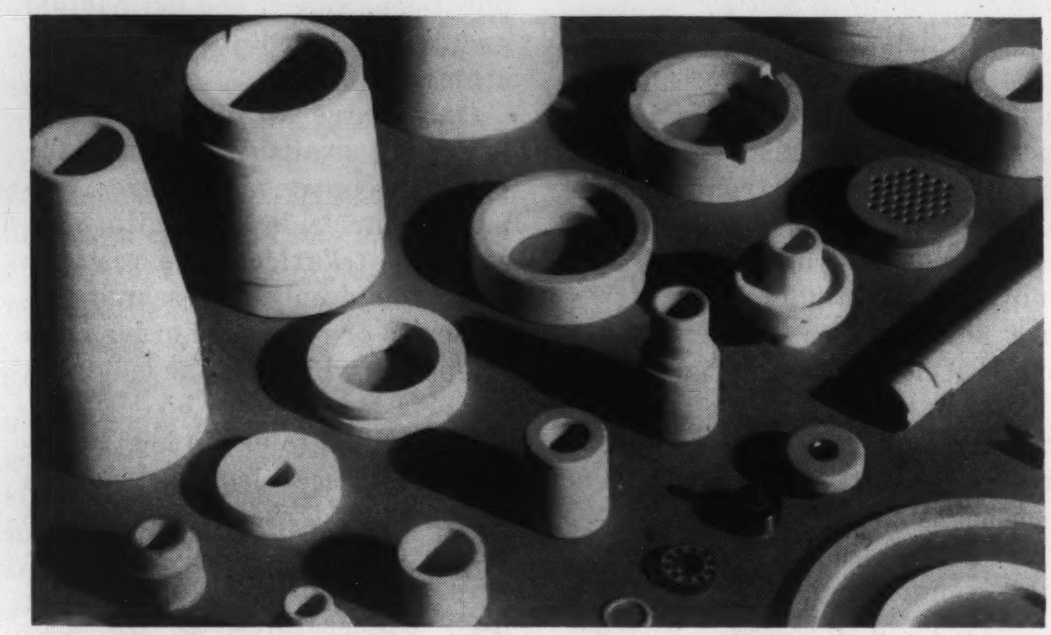
Hardness—The general range of hardness offered by ceramic materials is shown in Table 5 in comparison with that of hardened tool steel. The hardest ceramic is the recently synthesized cubic boron nitride (BN, Borazon). Cubic boron nitride and diamond are about equal in hardness, diamond scratching boron nitride under certain conditions, and boron nitride scratching diamond under others. The major benefit offered by cubic boron nitride is its resistance to temperatures over 3500 F; diamond burns at about 1600 F.

Developmental work indicates that in the near future a number of new ceramics will be developed in the Knoop hardness range of 2500 to 7000. These materials should find mechanical applications where hardness and wear resistance are required.

Strength—Many recently developed ceramic materials are much stronger than the older, classical ceramics. Compressive strengths as high as 500,000 psi have been reported for dense, high alumina ceramics. A compressive strength of 600,000 psi is reported for a

Diamonite Products Mfg. Co.

High temperature springs *are one of the newest applications for high alumina ceramics.*



Alite Div., U. S. Stoneware Co.

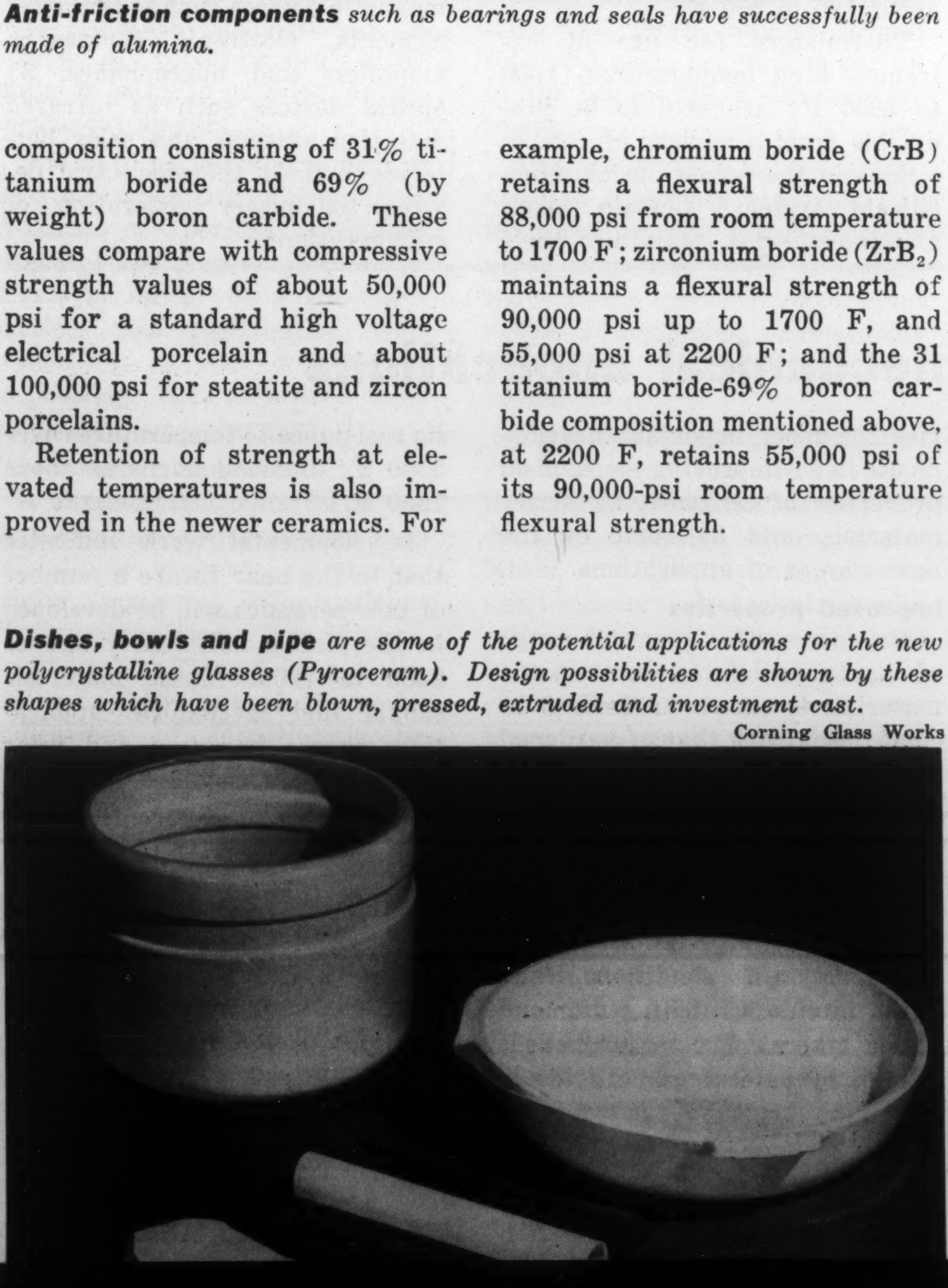
Anti-friction components *such as bearings and seals have successfully been made of alumina.*

composition consisting of 31% titanium boride and 69% (by weight) boron carbide. These values compare with compressive strength values of about 50,000 psi for a standard high voltage electrical porcelain and about 100,000 psi for steatite and zircon porcelains.

Retention of strength at elevated temperatures is also improved in the newer ceramics. For example, chromium boride (CrB) retains a flexural strength of 88,000 psi from room temperature to 1700 F; zirconium boride (ZrB_2) maintains a flexural strength of 90,000 psi up to 1700 F, and 55,000 psi at 2200 F; and the 31 titanium boride-69% boron carbide composition mentioned above, at 2200 F, retains 55,000 psi of its 90,000-psi room temperature flexural strength.

Dishes, bowls and pipe *are some of the potential applications for the new polycrystalline glasses (Pyroceram). Design possibilities are shown by these shapes which have been blown, pressed, extruded and investment cast.*

Corning Glass Works



Ductility—Though ceramics are generally poor under impact loading, many of the newer types of materials, such as certain alumina bodies, have been substantially improved in impact strength. Also, some ceramic materials may become less brittle and develop plastic properties at higher temperatures. At temperatures higher than 1850 F there are indications of increasing plasticity in a glass-free, polycrystalline alumina ceramic. This phenomenon is believed to be due to slipping at the grain boundary. Plasticity in single crystal alumina probably develops at still higher temperatures.

A recent research report indicates that some ceramic materials (e.g., cubic ionic crystals such as potassium bromide, cesium bromide, potassium chloride and lithium fluoride, and refractory materials such as magnesia) can be made ductile at room temperature. Results to date have been encouraging, and there is a good possibility that some polycrystalline ceramic materials that are ductile will be forthcoming.

Special treatments—Tempering, a process long used for strengthening glass, has been found to substantially improve strengths of certain polycrystalline ceramics. This type of treatment was not possible with older, classical ceramics because of their non-reacted quartz content, which required that the ceramic body be cooled slowly past the 1063 F quartz inversion temperature. (Rapid cooling past this temperature causes a rapid volume change which results in cracking of the body.)

Some of the new oxide porcelains with uniform thermal expansion or contraction characteristics can be rapidly quenched from high temperatures to induce compressive surface stresses, thus improving the strength of the body. The strength of dense, 95% alumina ceramic has been more than doubled by cooling the body rapidly from about 2500 F, and impact strength has been in-

Uses for Alumina Ceramics—A Partial List

- Automotive and aircraft spark plugs.
- Boats, slabs, crucibles and fixtures for brazing, sintering, melting and heat treating applications.
- Cutting tools.
- Dies for extrusion and injection molding.
- Envelopes for high frequency, power vacuum tubes.
- Furnace and burner parts, tubes, nozzles, muffles, and kiln furniture.
- Gages, both thread and plug.
- Guides for wire and thread.
- Insulators, e.g., coil forms, bushings, bases, cores, shafts and housings.
- Internal spacers for vacuum tubes (porous alumina).
- Nozzles, such as flow, shielding, blasting, spray-drying.
- Pebble mill grinding media.
- Pebbles for heat exchangers.
- Pump parts, e.g., plungers, casings, sleeve bearings, pressure seats and wear plates.
- Rotating seal faces.
- Thermocouple protection tubes.
- Valve components such as seats for ball and check types.

creased more than 20%.

Prestressing ceramics can, in some cases, substantially improve strength values. The prestressing operation is similar to the more highly developed technique used so successfully with concrete. Some oxide ceramics, after prestressing, improve in high temperature strength as well as room temperature compressive strength.

Alumina

Improvements in aluminum oxide ceramics have been brought about mainly by better control over the material itself (e.g., higher purity of raw material), and improvements in processing variables, such as modifications of forming techniques to provide denser, void-free bodies.

Typical properties of dense alumina ceramics, of various alumina contents, are shown in Table 6. In general, alumina ceramics are very hard and refractory, with excellent electrical properties, high mechanical strength, permanent dimensional stability and chemical inertness. Knoop hardness of alumina ceramics ranges from 1400 to 2000 (see Table 5). Strength, dielectric characteristics, thermal properties and degree of refractoriness generally improve with increasing alpha alumina (corundum) content. High alumina ceramics available today range from about 75 to nearly 100% alumina.

High purity alumina ceramics, with alpha alumina contents as high as 99.9+% can be used at temperatures up to 3500 F, are extremely inert, and have excellent resistance to reducing atmospheres. Single crystals of pure alumina (sapphire and ruby), made by flame fusion, are available in various forms.

Difficulties in fabricating the extremely high alumina ceramics have resulted in extensive work on various forming techniques, such as extrusion, hot pressing, injection molding, slip casting and isostatic pressing. Isostatic pressing is particularly beneficial in providing a uniform, dense, void-free structure. Improvements in control of forming operations have been achieved by use of such techniques as presintered compositions; additives to provide plasticizing, binding or lubricating qualities; and optimum particle size distribution to reduce void content and attain as near theoretical density as possible.

Low alumina ceramics are useful for applications where the maximum properties provided by high alumina content are not mandatory. Lower alumina ceramics are generally easier to fabricate and can be vitrified at appreciably lower temperatures (2800 to 3000 F) than high alumina bodies.

Alpha alumina is also used as an additive to improve specific properties of classical ceramics. For example, where thermal shock resistance is required alumina can be used to replace the quartz in the classical ceramic, reducing the abrupt change in thermal expansion characteristics of the body caused by the alpha-beta quartz inversion at 1063 F.

Applications—An accompanying list indicates some of the many current applications for alumina ceramics. Probably most widely discussed is the use of alumina as a cutting tool. Tool compositions are generally about 99% alumina.

Benefits offered by such tools include: 1) extreme rigidity prevents chattering, thus providing smoother cuts, 2) being nonmetallic, alumina does not weld to the metal and withstands better than metal tools the high temperatures developed at the cutting edge, 3) cuts can be made at speeds up to ten times those possible with previous tools, 4) tool life is reported to be as much as four times that for other types of tools, and 5) several materials previously considered unmachinable can be cut satisfactorily with alumina.

Alumina cutting tools are produced by various preforming, sintering or hot pressing techniques. Additives are used to control the microstructure. Crystal size must be uniform and below 10 μ. The preferred orientation of crystals is believed to prevent mechanical stresses on cooling.

Properties of one type of alumina cutting tool are reported to be as follows:

Specific Gravity	3.95
Compr Str, psi	450,000
Flex Str, psi	100,000
Mod of Elast, psi	60 x 10^6
Rockwell Hardness	A96.5
Ther Cond, Btu/hr/sq ft/°F/ft	18

Properties of ceramics for mechanical uses

TABLE 5—KNOOP HARDNESS OF SOME CERAMIC MATERIALS

Diamond	7000
Cubic Boron Nitride	7000
Boron Carbide	2800
Titanium Boride	2720
Silicon Carbide	2500
Titanium Carbide	2460
Zirconium Carbide	2090
Alumina	2000
Tungsten Carbide	1880
Cemented Carbides	1400 to 1800
Zirconium Boride	1560
Beryllia	1220
Quartz	800
Hardened Steel (60.5 Rockwell C)	740
Glasses	300 to 500
Calcite	130
Gypsum	30

TABLE 6—TYPICAL PROPERTIES OF DENSE HIGH ALUMINA CERAMICS[a]

% Alumina ➜	80	85	95	99+
PHYSICAL PROPERTIES				
Water Absorption, %	0.0	0.0	0.0	0.0
Specific Gravity	3.35	3.45	3.65	3.85
Max Service Temperature, F	—	2460	3000	3540
Specific Heat, Btu/lb/°F	—	0.18	0.19	0.22
Ther Cond (200 F), Btu/hr/sq ft/°F/ft	—	6.2	10.3	10.7
Coef of Ther Exp, per °F				
77-390 F	—	3.1 x 10^{-6}	3.7 x 10^{-6}	—
77-750 F	—	3.7 x 10^{-6}	4.0 x 10^{-6}	—
77-1100 F	3.5 x 10^{-6}	3.9 x 10^{-6}	4.3 x 10^{-6}	4.3 x 10^{-6}
77-1470 F	—	4.1 x 10^{-6}	4.5 x 10^{-6}	—
77-1830 F	—	4.3 x 10^{-6}	4.7 x 10^{-6}	—
MECHANICAL PROPERTIES				
Tensile Strength, psi	14,000	20,000	30,000	39,000
Flexural Strength, psi	29,000	41,000	45,000	47,000
Compressive Strength, psi	150,000	250,000	300,000	400,000
Modulus of Elasticity, psi	21 x 10^6	32 x 10^6	40 x 10^6	50 x 10^6
Impact Strength (Charpy), in.-lb	5.2	6.5	7.0	—
Hardness				
Mohs	8.5-9	9	9	9
Knoop	—	1450	1750	—
ELECTRICAL PROPERTIES				
Dielectric Strength, v/mil	200	200	250	300
Te Value, F	1290	1560	1960	2012
Dielectric Constant (77 F, 1 mc)	7.0	8.2	8.9	9.6
Power Factor (77 F, 1 mc)	0.0015	0.0009	0.00035	0.00027
Loss Factor (77 F, 1 mc)	0.010	0.007	0.003	0.003

[a] The values given are not maximum values and are dependent upon the minor components or fluxes used as well as a number of other factors.

TABLE 7—PROPERTIES OF TWO POLYCRYSTALLINE GLASSES[a]
(Pyroceram)

Grade ➜	Code 9605	Code 9606
THERMAL PROPERTIES		
Softening Temp, F	2460	2280
Spec Ht (77 F), Btu/lb/°F	0.102	0.105
Ther Cond (77 F), Btu/hr/sq ft/°F/ft	2.4	1.7
Coef of Ther Exp (77-570 F), per °F	7.7 x 10^{-7}	31.7x10^{-7}
MECHANICAL PROPERTIES		
Mod of Elast, 10^6 psi	19.8	17.8
Poisson's Ratio	—	0.24
Mod of Rupture, 1000 psi	37	32
Strength-Weight Ratio, 1000 psi[b]	14.1	12.3
Knoop Hardness		
50 Gm	1100	940
100 Gm	843	789
500 Gm	720	570
Abrasion (sand blast; plate glass = 1.0)	27	20
ELECTRICAL PROPERTIES		
Dielec Const (10^6 cps)		
77 F	6.1	5.62
570 F	6.3	5.80
Dielec Const (10^{10} cps)		
77 F	6.1	5.53
570 F	6.1	5.53
930 F	6.1	5.54
Dissip Factor (10^6 cps)		
77 F	0.0017	0.0024
570 F	0.014	0.013
Dissip Factor (10^{10} cps)		
77 F	0.0002	0.0003
570 F	0.0008	0.0006
930 F	0.0025	0.0018
Loss Factor (10^6 cps)		
77 F	0.010	0.014
570 F	0.078	0.075
Loss Factor (10^{10} cps)		
77 F	0.001	0.002
570 F	0.005	0.003
930 F	0.015	0.010
Volume Resistivity, Log 10 ohm-cm		
480 F	10.1	10
660 F	8.7	8.6
OTHER PROPERTIES		
Specific Gravity (77 F)	2.62	2.60
Water Absorption, %	0.00	0.00
Porosity (gas perm)	Gas tight	Gas tight

[a] Two grades listed are those on which most data have been developed. Both are opaque. Transparent grades are also available.
[b] Modulus of rupture ÷ specific gravity.
Source: Corning Glass Works.

Another growing use for alumina ceramics is as anti-friction materials in such applications as bearings and seals for high temperature operation. Requirements for such service include 1) sufficient strength to resist thermal and mechanical stresses, 2) resistance to wear, 3) no tendency to score, and 4) low coefficient of friction. The low coefficient of friction must also be stable over the service conditions encountered.

Alumina roller bearings have been made and require no lubrication. Ceramic sleeve bearings of all sizes are being used for high speed, high temperature applications.

Requirements for high temperature friction materials such as aircraft brake and clutch linings are similar to those for anti-friction materials with the exception that high rather than low, coefficients of friction are required. Cermets have been most successful in this type of application. More details are given in the section on Ceramics for High Temperature Uses.

The combination of excellent mechanical properties and good dielectric properties at high temperatures and frequencies has been responsible for much developmental work on alumina radomes for aircraft (see section on Ceramics for High Temperature Uses). Alumina is also used as insulating envelopes for vacuum tubes. Such envelopes are easily degassed at high bake-out temperatures, assuring longer vacuum life. Some porous alumina bodies are used for special parts such as tube supports in electronic tubes where refractoriness and ease of out-gassing are requirements.

Alumina single crystals (sapphire and ruby) are used for bearings, guides, gages, dies and other parts requiring wear resistance, hardness, and resistance to heat and corrosion.

Polycrystalline glass (Pyroceram)

A group of fine grained polycrystalline glasses, trademarked Pyroceram, has been introduced recently. A variety of compositions offering a range of physical properties are under development. Table 7 presents the latest thermal, mechanical and electrical data for two compositions currently available.

Polycrystalline glasses have high strength-to-weight ratio. Since the size, density and chemical composition of the crystals in the materials can be controlled, properties can be tailored to meet specific requirements. For example, a wide range of thermal properties is obtainable, with coefficients of thermal expansion ranging from slightly negative to 31.6×10^{-6} per °F. Extremely good thermal shock resistance can be provided by the proper combination of low thermal expansion and high tensile strength in certain grades of the material.

As pointed out in the section on Ceramics for Electrical and Electronic Uses, one type of Pyroceram has high frequency insulating properties comparable to those of the best electrical ceramics.

One of the most important benefits offered by these materials is the diversity in methods of fabrication possible, providing great flexibility in design. Proprietary formulations of the materials containing certain nucleating agents are melted as a conventional glass batch. The material can then be formed by any of the conventional glass forming methods, e.g., blowing, drawing, and pressing and rolling, or by such special forming techniques as centrifugal or investment casting. The formed part is then cooled and subjected to heat treatments that cause the nucleating agents to form a large number of submicroscopic crystallites, each crystallite acting as a center of crystal growth as heat treatment continues. The resulting product is a nonporous, fine-grained polycrystalline material.

Applications—The materials are so new that commercial applications are only now being developed. The properties of the materials indicate their suitability for a number of mechanical and chemical applications such as chemical processing equipment, and domestic products.

3. Ceramics for high temperature use

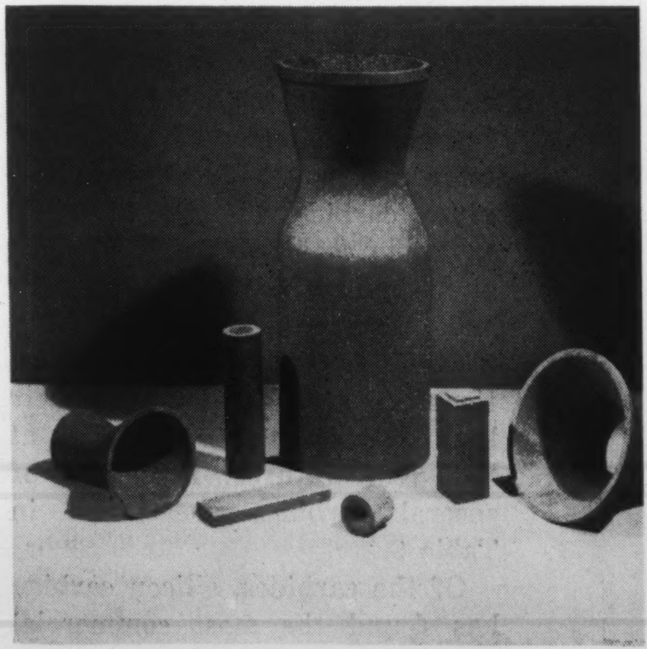
Refractoriness and resistance to high temperatures are distinguishing characteristics of most ceramic materials. The discussion here is primarily concerned with the newer high temperature refractory materials, and cermets made from them. Furnace and kiln refractories are not included.

Of the large number of possible refractory oxides, carbides, nitrides, borides, silicides and aluminides, only a relative few have so far been developed commercially. However, many seem to have a combination of properties warranting commercial production. Although high melting points of some of the materials are indicative of good high temperature stability, deficiencies in other properties, such as strength, thermal shock resistance and fabricability, complicate development problems.

Oxides

Pure refractory oxides such as alumina, beryllia, magnesia and zirconia have exceptionally good resistance to oxidation at high temperatures. They are generally hard and chemically inert, providing good resistance to erosion and corrosion. A large number of oxides have high refractoriness. Table 9 shows properties of some commerical oxides.

Alumina, one of the most important commercial oxides, is one of the most chemically stable and strong of the refractory oxides,



Norton Co.

Rocket nozzle *utilizes the good mechanical and thermal properties of densified silicon carbide.*

particularly at moderately high temperatures. At temperatures as high as 3275 F it is resistant to all gases except fluorine. It can be used in either oxidizing or highly reducing atmospheres at temperatures up to about 3450 F, or 3540 F for short periods. Alumina is discussed in further detail in the section on Ceramics for Mechanical Applications.

A new refractory material, primarily intended for high temperature thermal insulation, consists of alumina bubbles or hollow spheres, bonded and fired. Supplied as a castable, it has a maximum use temperature of about 3300 F.

Cermets — Cermets of metal-bonded refractory oxides have good thermochemical stability and load-bearing strength at relatively high temperatures. The oxide-base cermets of greatest current commercial interest are chromium-bonded alumina-base materials. Properties of two such cermets are given in Table 9. They have exceptionally good high temperature strength (one type having a modulus of rupture of 11,800 psi at 2400 F), good erosion and wear resistance, and excellent resistance to molten metals and oxidation. Quantities of tungsten, molybdenum and titanium oxide are added to various grades to improve specific properties such as thermal shock resistance.

Carbides

Carbides are among the most refractory materials known. Melting points of some of the higher temperature carbides are: hafnium carbide (HfC), 7520 F; tantalum carbide (TaC), 7025 F; zirconium carbide (ZrC), 6370 F; and titanium carbide (TiC), 5660 F. One of the major limitations of the carbides is their limited resistance to oxidation at high temperatures. Properties of several carbides are given in Table 9.

Of the carbides, silicon carbide has found the most commercial use as refractories. Tungsten carbide, titanium carbide and chromium carbide have been used primarily in the form of cermets. Boron carbide is useful as an abrasive, and is finding applications in nuclear reactors because of its high thermal neutron absorption cross section.

Some carbides, such as silicon carbide, as well as some nitrides and silicides, oxidize slowly at high temperatures and produce a protective coating of viscous silica glass which retards further oxidation.

Table 8 shows properties of various types of commercial silicon carbide and boron carbide. Silicon carbide can be used at temperatures up to 2750 F, and at considerably higher temperatures for short periods of time.

Originally, silicon carbide bodies were prepared with a silicate bond. Substantial improvements in shock resistance, thermal conductivity and hot strength were obtained by using a silicon nitride bond. The silicon nitride phase of such structures has good resistance to corrosion, and a dissociation temperature of about 3500 F. The recently developed densified silicon carbide is actually a silicon carbide-bonded silicon carbide and has a maximum working temperature of 4200 F in an inert atmosphere and 3000 F in an oxidizing atmosphere. It has high strength and extremely good resistance to abrasion and corrosion at high temperatures.

Boron carbide is commercially available as a sintered or hot pressed body in densities ranging from about 60 to 95% of theoretical. The boron content ranges from about 75% by weight for the B_4C type to 82% by weight for the B_6C type. Boron carbide has a maximum service temperature of 4100 F in inert atmospheres and 1000 F in oxidizing atmospheres.

Cermets—Carbide-base cermets, though easier to bond than the oxide-base types, generally have poorer load-bearing characteristics. Commercial carbide-base cermets include titanium carbides bonded with metals such as nickel, cobalt, chromium and molybdenum; tungsten carbide bonded with cobalt; and chromium carbides bonded with nickel and copper.

Titanium and tungsten carbide-base cermets have probably been the most widely used carbide cermets. Improvements in thermal shock resistance of nickel-bonded titanium carbides have been obtained by adding such metals as aluminum, chromium and molybdenum to the nickel. Titanium and tungsten carbide-base cermets have been used to handle sodium, sodium-potassium and other metals at temperatures exceeding 1050 F.

One experimental cermet, con-

TABLE 8—PROPERTIES OF SOME COMMERCIAL CARBIDES

Type ➡	Silicon Carbide (silicate bonded)	Silicon Carbide (silicon nitride bonded)	Silicon Carbide (densified)	Boron Carbide
Specific Gravity	2.57	2.87	3.10	2.40[a]
Porosity, %	9-17	6-10	Negligible	Negligible
Mean Spec Ht (0-2550 F), Btu/lb/°F	0.285	0.288	0.331	—
Mean Ther Exp (0-2550 F), per °F	2.4×10^{-6}	2.4×10^{-6}	2.17×10^{-6}	1.73×10^{-6}
Modulus of Rupture (77 F), psi	2200	5500	24,000	50,000
Ther Cond (2200 F), Btu/hr/sq ft/°F/in.	109	113.5	293[b]	188
Tensile Strength (77 F), psi	Very low	3000	25,000	22,500
Compressive Strength (77 F), psi	15,000	20,000	150,000	420,000
Modulus of Elasticity (77 F), 10^6 psi	13.2	17	68	42
Max Service Temperature, F				
Inert Atmosphere	3200	3200	4000	4100
Oxidizing Atmosphere	2900	3000	3000	1000

[a] Boron carbide is available in specific gravities ranging from 1.9 to 2.52.
[b] 1832 F.
Source: Carborundum Co.

sisting of molybdenum and silicon carbide, shows an increase in strength with temperature. The room temperature flexural strength of 42,200 psi increases to 71,900 psi at 1800 F.

Borides

Borides of the high melting metals have melting points ranging from 3600 F to 5500 F, low volatility, low electrical resistivity, high hardness and high stability. They are not particularly resisttant to oxidation at high temperatures (2400 to 2700 F or above). Their resistance to various types of aqueous or gaseous corrosion is good, but not much better than that of the carbides and silicides. Some of the more interesting borides are molybdenum boride (Mo_2B or MoB), titanium boride (TiB_2), zirconium boride (ZrB_2), iron boride (Fe_2B or FeB), chromium boride (CrB) and manganese boride (Mn_2B or MnB).

Cermets — Although all boride materials are still experimental, some quite interesting cermet compositions include chromium-bonded molybdenum boride, iron-bonded iron boride, iron-bonded manganese boride, and chromium boride bonded with nickel, iron or cobalt.

In general, boride-base cermets are not as strong as titanium carbide at room temperature, but may be stronger at elevated temperatures. They are somewhat brittle and do not possess high load-bearing ability.

Nitrides

Most nitrides are relatively brittle and have low oxidation resistance. The most successful refractory nitrides developed to date are boron nitride (BN) and silicon nitride (Si_3N_4).

Hexagonal boron nitride (not to be confused with cubic boron nitride, having hardness equivalent to that of diamond) can be used at temperatures up to 3000 F and higher under special conditions. It is quite stable at high temperatures, and is not wetted by molten glass or certain nonferrous metals. It also has good resistance to thermal shock, lubricating qualities similar to graphite, and good dielectric qualities.

Silicon nitride can be used in neutral or reducing atmospheres at temperatures up to 3400 F. It has good thermal shock resistance, and excellent resistance to molten nonferrous metals and most acids. It withstands attack by molten steel and cast iron for short periods of time. Silicon nitride has a modulus of rupture about midway between that of alumina and silicon nitride-bonded silicon carbide.

Cermets—Nitride-base cermets are in early stages of development. Certain compositions based on titanium nitride seem most promising; they consist of a solid solution of titanium nitride and titanium carbide bonded with chromium or a nickel-cobalt alloy.

Silicides

Molybdenum disilicide is the most important silicide in commercial production today. However, several types of massive silicides have exceptional resistance to oxidation at high temperatures as a result of the formation, during exposure to temperature, of a protective surface film of silica. In general, the silicides of molybdenum, chromium, tungsten, titanium, columbium, tantalum and zirconium have sufficiently high melting points to be investigated as refractories. Silicides of chromium and titanium have been studied most extensively and should find commercial use soon.

Little information is available on the physical properties of silicide bodies, but in general they have excellent thermal shock resistance and low electrical resistivity, and are hard and brittle at room temperature. They have at least limited plasticity at elevated temperatures.

Aluminides

Most of the successful work on aluminides has centered around cermet compositions. Molybdenum-bonded aluminides have good high temperature stability and resistance to oxidation, but poor strength and thermal shock resistance.

Nickel-bonded aluminides have good thermal shock resistance, good high temperature oxidation resistance and some room temperature ductility, but strengths are relatively low.

Other Articles

For more information on the materials discussed in this manual, see the following articles published recently in M/DE:*

Electrical and Electronic Uses
- Where to Use the New Semiconductor Materials, Mar '58, p 114.

Mechanical Uses
- Man-Made Material Is Hard as Diamond, May '57, p 194.
- Pyroceram: A Strong New Ceramic, July '57, p 142.

High Temperature Uses
- New Alumina-Type Cermets, Feb '58, p 112.
- Improved Silicon Carbide for High Temperature Parts (silicon carbide bond), Oct '56, p 92.
- Specially Bonded Silicon Carbide (silicon nitride bond), Nov '54, p 83.
- Boron Carbide Looks Promising for Nuclear Uses, Dec '56, p 96.
- Boride Parts Resist Molten Zinc, June '56, p 132.
- Boron Nitride, Jan '56, p 88.
- Silicon Nitride Refractory, Jan '58, p 115.

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* See also *Materials Selector* issue, mid-Sept '57, pp 225-8.

New uses for refractories and cermets

Because of space limitations, only some of the newer applications for refractory ceramics and cermets are discussed here. The more conventional applications, such as crucibles, thermocouple protection tubes, gaskets, pump components, pouring spouts and flame holders, are relatively well known.

Friction materials—The greater weights and higher speeds of transportation equipment such as aircraft have necessitated the development of high temperature (800 to 2000 F) friction materials for such uses as brake and clutch linings. Such friction materials must have not only the refractoriness of ceramics, but also sufficient strength to resist thermal and mechanical stresses, a low

TABLE 9—PROPERTIES OF SELECTED REFRACTORIES FOR NUCLEAR USES

Material ↓	Melting Point, C	Bulk Density, gm/cu cm[b]	Ther Neutron Abs Cross Section, sq cm/cu cm	Ther Cond, gm-cal/sec/sq cm/°C/cm	Coef of Ther Exp, 10^6/per °C	Mod of Elast, 10^{-6} psi	Spec Ht, cal/gm/°C	Pref Fab. Methods[i]	Poss. Ther Reactor Uses[j]
Alumina (Al_2O_3)	2015±15	3.79	0.0101	0.069 (100C) 0.021 (600C) 0.013 (1200C)	6 (20C) 7 (500C) 9 (1000C)	52 (20C) 50 (800C) 32 (1400C)	0.21 (20C) 0.25 (500C) 0.28 (1000C)	CS, ES, CPS	F, S
Beryllia (BeO)	2350±30	2.86	0.00074	0.500 (100C) 0.107 (600C) 0.039 (1200C)	8 (100C) 8 (500C) 9 (1000C)	45 (20C) 28 (800C) 12 (1400C)	0.24 (20C) 0.50 (500C)	HP, CPS, ES, CS	F, M, R, S
Hafnia (HfO_2)	2900±25	9.68	3.18	—	5.8 (250-1300C)	8.2 (20C)[e]	0.174 (400C) 0.197 (1000C)	CS, ES, CPS, HP	C, Sh
Gadolinia (Gd_2O_3)	2350±20	7.40[c]	1090	0.005 (1000C)	10.5 (25-1000C)	18.0 (20C)	0.176 (400C) 0.1956 (1000C)	CS, ES, CPS	C, Sh
Samaria (Sm_2O_3)	2350±20	7.43[c]	167	0.005 (1000C)	9.9 (25-1000C)	26.5 (20C)	0.179 (400C) 0.205 (1000C)	CS, ES, CPS	C, Sh
Magnesia (MgO)	2800	3.58	0.0032	0.082 (100C) 0.026 (600C) 0.014 (1200C)	11 (100C) 13 (500C) 15 (1000C)	12 (20C)	0.23 (20C) 0.26 (500C) 0.28 (1000C)	CS, ES, CPS	F, S
Thoria (ThO_2)	3220±50	9.6	0.160	0.020 (100C) 0.008 (600C) 0.0076 (1200C)	8 (100C) 9 (500C) 9 (1000C)	21 (20C) 18 (800C) 14 (1400C)	0.058 (50C)	CS, ES, CPS	F, S
Titania (TiO_2)	1830	4.17	0.176	0.015 (100C) 0.008 (600C) 0.0076 (1200C)	7.5 (100-500C)	12.7-15.5(20C)	0.168 (0C)	CS, ES, CPS	S
Urania (UO_2)	2878±22	10.02	0.165	0.018 (100C) 0.008 (600C) 0.006 (1000C)	11.2 (27-1260C)	25 (20C)	0.056 (17C)	CS, ES, CPS, HP	F, S
Stabilized Zirconia (ZrO_2+5%CaO)	2600	5.35	0.00571	0.004 (100C) 0.004 (600C) 0.0049 (1200C)	7.2 (70-1000C)	36 (20C)	0.12 (20C) 0.16 (500C)	CS, ES, CPS	S
Beryllium Carbide (Be_2C)	Decomp. 2100	2.44[c]	0.0010	0.056 (20C)	10.8 (38-982C)	45 (20C)[f]	—	HP	F, M, R, S
Boron Carbide (B_4C)	2450	2.51[c]	82.0	0.065 (20C)	4.5 (25-800C)	65 (20C)	0.443 (25C)[k]	HP	C, Sh
Silicon Carbide (SiC)	Decomp. 2200	3.2[c]	0.00647	0.49 (600C; recryst.)	4.7 (20-1500C)	—	0.143 (0C)	CS, ES, CPS, HP	F, S
Tantalum Carbide (TaC)	3880±150	14.48[c]	0.964	0.053 (20C)	8.2 ± 0.8 (20-2380C)	—	—	HP	S
Titanium Carbide (TiC)	3140	4.93	0.277	0.41 (20C)	7.42 (24-500C)	51 (20C)[g]	0.201 (25C)[l]	HP	
Uranium Carbide (UC_2)	2400	11.28[c]	0.192	0.082 (20C)[d]	—	—	0.035 (100C)[l]	HP	F
Tungsten Carbide (WC)	2777	15.70[c]	0.915	—	5.2 (20C) 7.3 (1930C)	102.5 (20C)	—	HP	S
Zirconium Carbide (ZrC)	3530±125	6.7	0.0072	0.049 (20C)	6.73 (24-500C)	49 (20C)[h]	—	HP	F, S
Graphite (Cg)	3700±100	1.55	0.000350	0.298 (100C) 0.154 (600C) 0.105 (1000C)	3.34 (25-1800C)	1.0 (20C)	0.3 (20C)	Extruded, graphitized at 3000 C and machined	F, M, R, S
Boron	2300±300	2.3	96	—	8.3 (20-750C)	—	0.307 (50C) 0.472 (500C) 0.510 (900C)	HP	C, Sh
Molybdenum Disilicide ($MoSi_2$)	1870	6.2	0.065	0.075 (20-200C)	—	—	—	HP	F, S
80 SiC-2 C-18% Si	1400[a]	3.1	0.00659	0.5 (50C) 0.06 (1000C)	4.2 (20C)	35.8 (20C)	0.228 (400C) 0.252 (700C) 0.267 (1000C)	Impregnation of formed C or SiC with Si	F, S
72 Cr-28% Al_2O_3	1300[a]	5.95	0.147	0.04 (20C)	5.85 (25-800C)	47.2 (25C)	—	CS, CP, HP	F, S
30 Cr-70% Al_2O_3	1300[a]	4.68	0.056	0.023 (20C)	8.65 (25-800C) 9.45 (25-1315C)	52.3 (25C)	—	CS, CPS, HP	F, S
80 TiC-20% Ni (K-151a)[l]	1200[a]	5.8	0.311	0.080 (20C)	5.0 (25-1000C)	56.7 (1000C)	—	CPS, HP	S

[a] Max continuous service temperature.

[b] Values in table used in calculating thermal neutron cross section.

[c] Theoretical.

[d] Density: 10 gm/cu cm.

[e] Sintered at 1500 C.

[f] Porosity 6-8%.

[g] Sintered with 5% cobalt.

[h] Hot pressed.

[i] CS = cast and sintered; ES = extruded and sintered; CPS = cold pressed and sintered; HP = hot pressed.

[j] F = fuel elements; M = moderator; R = reflector; C = control devices; S = structural parts; Sh = neutron shield.

[k] Calculated.

[l] Trademark of Kennametal, Inc.

Source: Warde, J. M., "Refractories for Nuclear Energy," *The Refractories Institute Bulletin*, No. 94, Feb. '56; an extensive bibliography is available from the author. Note: The metric system has become traditional for expressing engineering data in the nuclear field and is therefore used here.

wear rate, no tendency to score, and a high coefficient of friction that is stable over the service temperatures encountered.

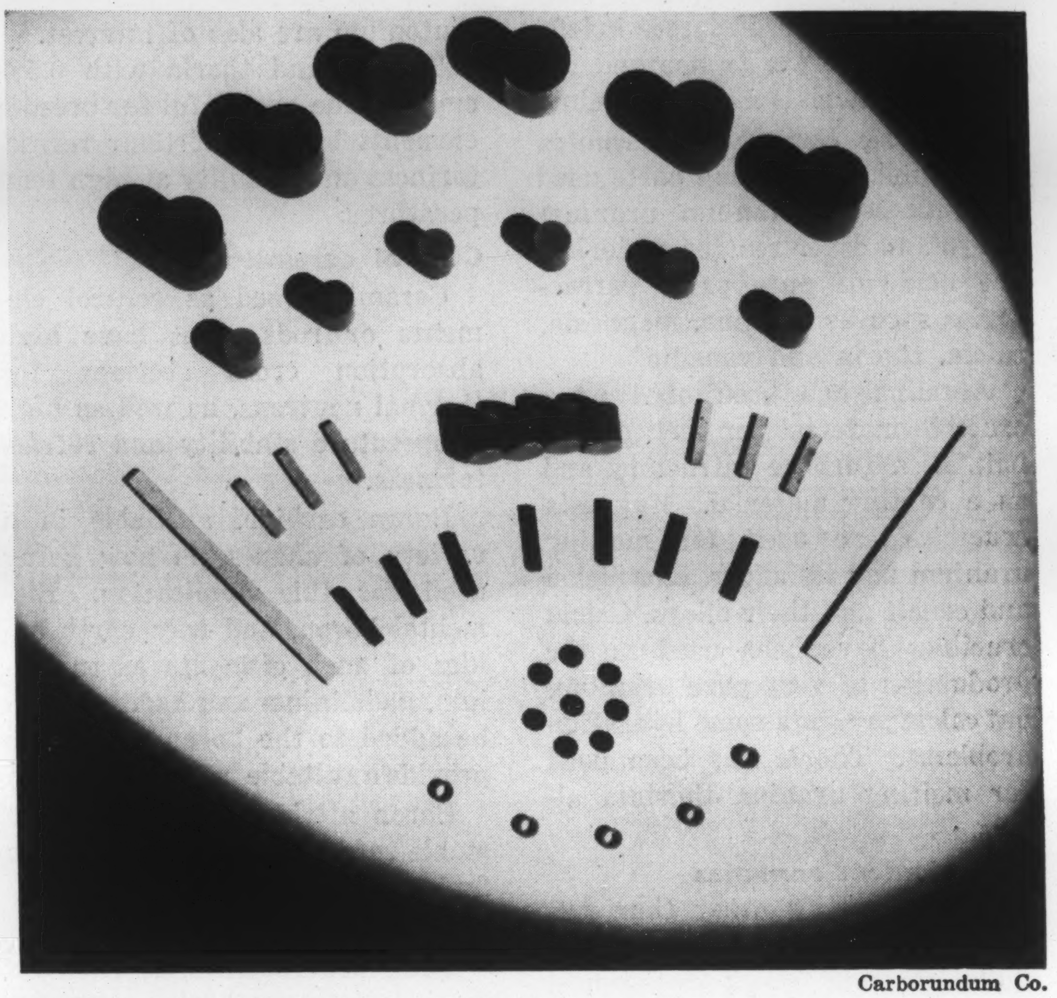
Cermets have been the most successful in meeting these requirements. The metallic phase conducts heat away from the face of the material; the ceramic phase provides the wear resistance. Though most such materials are proprietary and exact compositions are not reported, in general they consist of iron or copper combined with a silica or aluminosilicate (mullite or kyanite) ceramic phase. In some cases, the less abrasive oxides can be used as the ceramic phase. Small proportions of graphite can be used to modify frictional characteristics.

Aircraft radomes — The temperatures encountered with present and planned supersonic speeds make refractory ceramics a natural possibility for aircraft radomes. The properties required for such use include low dielectric loss and stable dielectric constant over the service temperature range, and a homogeneous structure having uniform density, high erosion resistance, high mechanical strength and good thermal shock resistance.

High alumina ceramics are one of the most promising of the materials that meet these design requirements. Alumina is discussed in detail in the section on Ceramics for Mechanical Applications.

Rocket nozzles—Design requirements for rocket nozzles include stability at extremely high temperatures, excellent thermal shock resistance, and resistance to corrosive gases and erosion caused by high velocity gas streams. The erosion that does occur should be consistent around the periphery of the nozzle throat to ensure even burning and true flight.

Many refractory materials, ceramic coatings, and cermets are currently being evaluated for this use. Some of the most promising are flame sprayed alumina and zirconia coatings, both silicon carbide- and silicon nitride-bonded silicon carbide, and the chromium-alumina type cermets.



Carborundum Co.

Nuclear fuel elements *are produced in a variety of shapes from urania, urania-alumina and urania-thoria compositions.*

4. Ceramics for nuclear uses

Ceramic materials are playing an increasingly important part in nearly all categories of nuclear equipment because of their thermal stability, corrosion resistance and refractoriness, and because of the different neutron capture and scatter characteristics available in different compositions. Although ceramics are more susceptible to damage from severe irradiation than metals, they can be heat treated to anneal the damage; in most cases nearly complete recovery is achieved.

Effects of radiation—Radiation damage to ceramics consists primarily of defects in the lattice. Ionic crystals with simple structures show least damage; anisotropic structures and highly covalent crystals are more sensitive to damage. Some ceramic bodies of small grain and random orientation, such as alumina, show relatively little structural change on exposure, though thermal conductivity is decreased in most instances.

In the case of graphite, and it is probably true for most ceramics, less radiation damage occurs at higher temperatures, than at room temperature. Damage in graphite is caused by the displacement of carbon atoms, resulting in lattice vacancies and interstitial carbon atoms which have a direct effect on physical properties. Annealing at high temperatures produces virtually complete recovery.

Radiation damage to electrical insulators such as alumina zircon, beryllia, sillimanite ($Al_2O_3 \cdot SiO_2$), mica, magnesia and quartz results in decreased electrical resistivity and changes in surface color. For the most part these changes are reversible by annealing.

Table 9 lists properties of a variety of materials that are either being used or have potential use in nuclear equipment. The following section discusses briefly the various areas of use and the ceramic materials most promising.

Processing equipment ceramics

Crucibles, molds and parts used for processing uranium, uranium alloys and other reactor materials are made of pure oxide refractories such as alumina, magnesia, calcia, thoria and vanadia.

Alumina has been used as a crucible material for melting cobalt, as a furnace refractory and as a coating material. Magnesia crucibles are used for melting uranium and its alloys, and nickel and cobalt and their alloys. Calcia crucibles have been used in the production of very pure uranium, but calcia presents some hydration problems. Thoria has been used for melting uranium-thorium alloys.

Fuel element ceramics

The properties other than nuclear, needed for fuel elements include thermal shock resistance, resistance to corrosion and high thermal conductivity (to lower the temperature of the fuel and reduce stresses developed in the element).

Uranium oxide, which generally meets these requirements, is used in granular and bulk form and can be fabricated into rods, pellets, plates or blocks. Urania (UO_2) on heating in air oxidizes to U_3O_8 with an accompanying volume increase. Thus it must be fabricated in an oxygen-free atmosphere. Stable solid solutions of urania-thoria can be produced by adding 20% or more of ThO_2 to U_3O_8; firing reduces the latter to UO_2.

The desirability of high thermal conductivity has stimulated work on uranium carbide (UC and UC_2), uranium nitride (UN), and uranium silicide (USi_2). Various refractory additives which have been considered include silicon carbide, magnesia, graphite and beryllia. Cermets containing uranium, such as combinations of uranium and Cr-Al_2O_3 or Si-SiC, and Al-UO_2, offer relatively high operating temperatures with good heat transfer characteristics. Various ceramic forms of thorium and plutonium are also of interest.

Thoria, and thoria with 0.5% cupric oxide, are useful for breeder elements because of their refractoriness and stability at high temperatures.

Control ceramics

Ceramics used as control elements or rods must have high absorption cross sections for thermal neutrons, as well as high temperature stability and refractoriness.

Boron carbide, available in a variety of shapes, is now being used for this application. Elemental boron, and rare earth oxides of such elements as samarium, gadolinium and hafnium, can be added to the boron carbide to provide a suitable refractory body.

Boron nitride and some of the stable refractory borides may also find use in control devices.

Moderator ceramics

Both moderators and reflectors must have very high scattering cross sections and low neutron absorption characteristics. High density graphite probably is used most extensively; beryllia is also used.

Beryllium carbide is potentially useful as a moderator. The oxides, nitrides and carbides of beryllium and zirconium are of interest as reflectors. Dense graphite can be used for tubes to contain reactor coolants, neutron filters and attenuators, and containers for experimental irradiation.

Shielding ceramics

Elemental boron, boron carbide and boron nitride are useful shielding materials, since they contain the boron isotope B^{10}, an effective absorber of thermal neutrons. Boron carbide can also be used as a granular fill, in block form, or embedded in other materials.

Cement and concrete filled with materials having high neutron capture cross section are used for large shielding installations. Filler materials include metallic iron, iron ores, barytes ($BaSO_4$), colemanite ($2CaO \cdot 3B_2O_3 \cdot 5H_2O$) and ferrophosphates. Magnesium oxychloride cement is of interest because of its high water content; however there is some question as to its stability.

Structural ceramics

Ceramics such as alumina, beryllia, zirconia, magnesia, some silicides and silicon carbide are potentially useful as structural materials since they maintain strength and load-bearing properties at high temperatures. Cermets such as chromium-alumina and silicon-silicon carbide may also be useful. Refractory insulating materials such as bubble alumina, alumino-silicate fibers and diatomaceous earth can be used for thermal insulation.

Waste disposal ceramics

In solving the critical problem of disposal of reactor wastes, montmorillonite clay is used to absorb fission products; the clay is then fused prior to disposal. A more recent method involves fusing the radioactive wastes in a nepheline syenite glass before burial.

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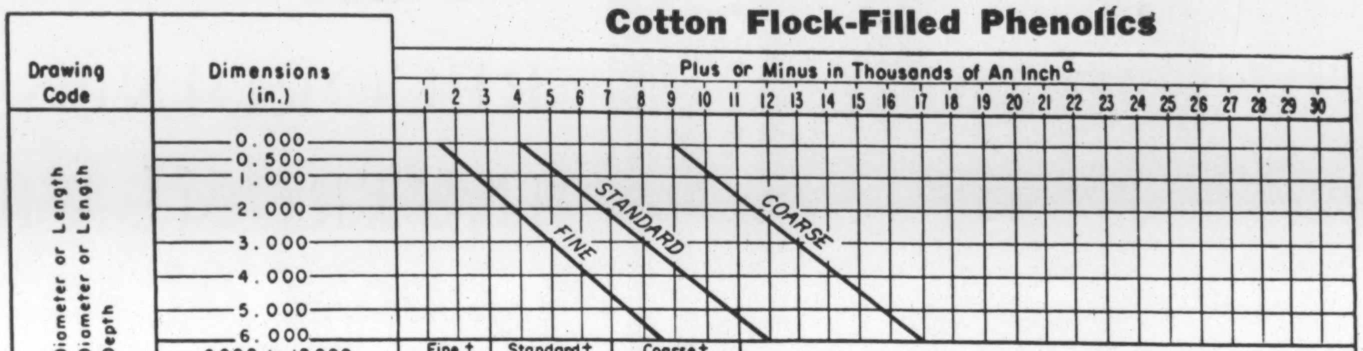
FILE FACTS

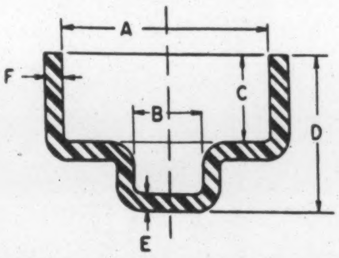
Recommended Design Tolerances for Plastics Moldings—Part 2

Cotton Flock-Filled Phenolics



A = Diameter or Length
B = Diameter or Length
C = Depth

Drawing Code	Dimensions (in.)	Fine ±	Standard ±	Coarse ±
A, B, C	6.000 to 12.000 For each inch over 6.000 add (in.)	0.0015	0.002	0.0025
	Over 12.000 For each inch over 12.000 add (in.)	0.002	0.003	0.005
HEIGHT D	Single Cavity 0.000-1.000	0.006	0.008	0.010
	Multiple Cavity 0.000-1.000	0.008	0.010	0.012
	For each inch over 1.000 add (in.)	0.002	0.005	0.008
BOTTOM WALL E	0.000 to 0.100	0.003	0.005	0.008
	0.100 to 0.200	0.003	0.005	0.008
	0.200 to 0.300	0.003	0.005	0.008
SIDEWALL F DIMENSION[b]		Section thickness to be held relatively constant		
F' Variation in wall thickness due to eccentricity, 0.005-0.007 in. Interlocking reduces this.				
DRAFT ALLOWANCE		1/8°	1/4°	1°



[a] These tolerances do not apply to screw threads, gear teeth or fit of mating parts; dimensions in these classifications can generally be held to closer limits. These tolerances do not include allowance for aging characteristics of material.

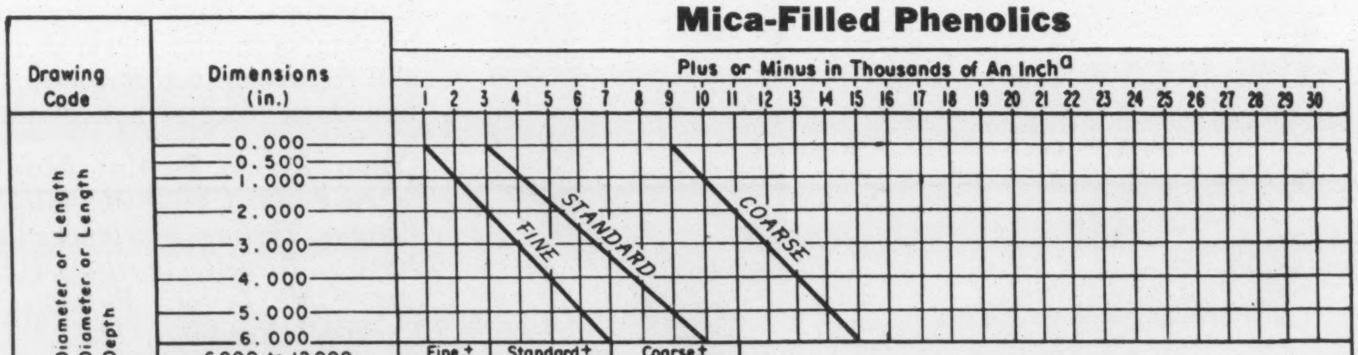
[b] For further information see discussion in Plastics Engineering Handbook.

DWG. CODE			
D, E	Compression Molded. For projected area over 20 sq in.	Fine	Add 0.001 in. for each additional 10 sq in.
		Standard	Add 0.002 in. for each additional 10 sq in.
		Coarse	Add 0.003 in. for each additional 10 sq in.

PLUS OR MINUS TOLERANCE IN THOUSANDTHS OF AN INCH (F = Fine; S = Standard; C = Coarse)

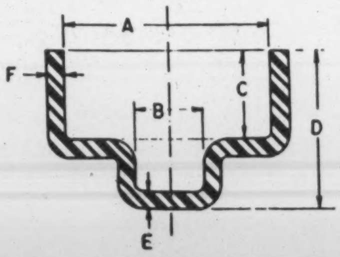
	Transfer, Jet, or Injection molded. Any area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
D	Single cavity				F		S		C														
D	Multiple cavity						F		S		C												
D	For each inch of depth over 1.000 add (in.)	0.0015																					

Mica-Filled Phenolics



A = Diameter or Length
B = Diameter or Length
C = Depth

Drawing Code	Dimensions (in.)	Fine ±	Standard ±	Coarse ±
A, B, C	6.000 to 12.000 For each inch over 6.000 add (in.)	0.001	0.0015	0.002
	Over 12.000 For each inch over 12.000 add (in.)	0.0015	0.003	0.005
HEIGHT D	Single Cavity 0.000-1.000	0.004	0.006	0.008
	Multiple Cavity 0.000-1.000	0.006	0.008	0.010
	For each inch over 1.000 add (in.)	0.002	0.003	0.004
BOTTOM WALL E	0.000 to 0.100	0.003	0.005	0.008
	0.100 to 0.200	0.003	0.005	0.008
	0.200 to 0.300	0.003	0.005	0.008
SIDEWALL F DIMENSION[b]		Section thickness to be held relatively constant		
F' Variation in wall thickness due to eccentricity, 0.005-0.007 in. Interlocking reduces this.				
DRAFT ALLOWANCE		1/8°	1/4°	1°



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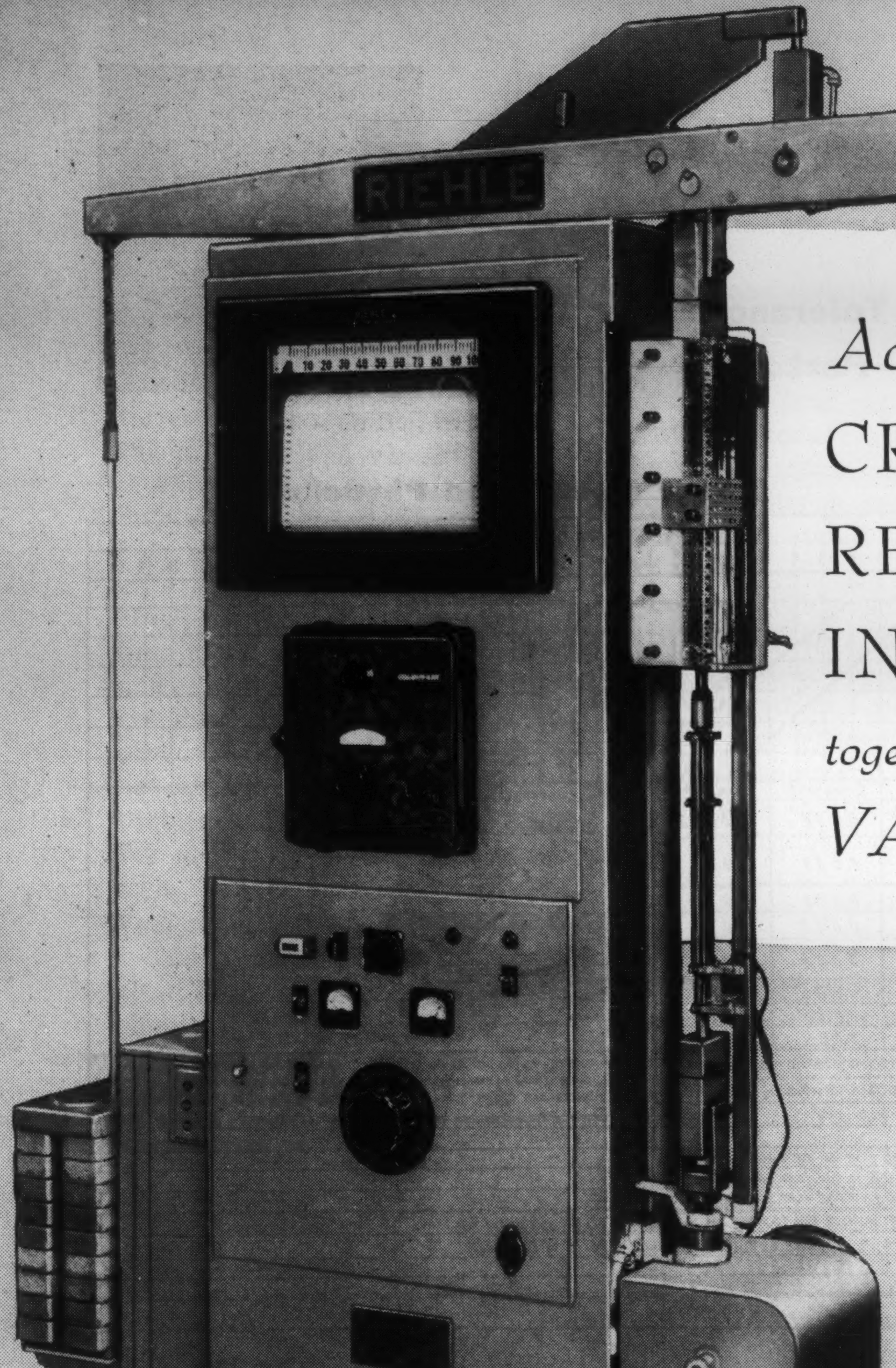
		Standard	Add 0.002 in. for each additional 10 sq in.
		Coarse	Add 0.003 in. for each additional 10 sq in.

PLUS OR MINUS TOLERANCE IN THOUSANDTHS OF AN INCH (F = Fine; S = Standard; C = Coarse)

	Transfer, jet, or injection molded. Any area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
D	Single cavity		F		S		C																
D	Multiple cavity				F		S		C														
D	For each inch of depth over 1,000 add (in.)	0.001																					

Source: *Plastics Engineering Handbook* of the Society of the Plastics Industry, Inc., Reinhold Publishing Corp., 1954.



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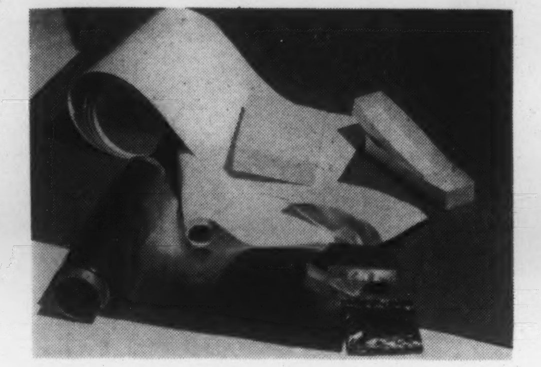


***Aluminum foil,** paper and other materials can be laminated with Goodyear's new polyester film.*

Heat-Seal Polyester Film Laminates to Wood, Metal

■ A new, heat sealable polyester film has been developed by Goodyear Tire & Rubber Co., Akron, Ohio as a laminating film for leather, wood, textiles, ferrous and nonferrous metals, paper and some plastics. According to E. J. Thomas, president of Goodyear, "Videne A has extremely high abrasion resistance, has good outdoor aging resistance, and has excellent adhesive, electrical and forming properties."

The film is presently available in limited quantities from Goodyear's facilities in Akron at a price of $2.25 per lb. It is supplied in clear and satin finishes, in gages from 2 to 7½ mils, and in widths up to 54 in. The company is constructing a $9 million plant in Apple Grove, W. Va. for full scale production of the film. Price is expected to drop considerably once production gets going.

Goodyear scientists describe Videne A polyester film as an unoriented, amorphous, thermoplastic material which cannot be crystallized. It differs from other plastics in two major respects: 1) it can be adhered under heat and pressure to textiles, metals, wood, paper and certain plastics without adhesives; and 2) it can be vacuum formed and drawn to the limits of supporting materials.

Applications

The film is said to act as a decorative and protective surface for glass, cotton, wool, Dacron, Orlon and nylon fabrics. It can be laminated to ferrous and nonferrous metal surfaces to produce outdoor sheeting, wall panels, doors, sills, trays, table tops, and interior and exterior automobile trim.

According to Goodyear, Videne A seals under heat and pressure to all woods and composition wood surfaces without adhesives to provide a protective prefinished surface. In wood combinations, such as plywood, the film can be used as an adhesive to hold the plies together. Videne A-paper laminations are said to make good wall coverings, decorative papers and electrical tapes.

The film is said to laminate to most rigid and semi-rigid plastics under heat and pressure; Videne A coated plastics can be used as bathtubs, sinks, light fixtures, boat surfaces, caskets, wall tiles and trays.

PROPERTIES OF VIDENE A

PHYSICAL PROPERTIES	
Tensile Strength, psi	9000
Elongation, %	4
Falling Ball Impact Strength, in.	11
Mullens Burst Strength, psi	60
Elmendorf Tear Strength, gm/mil	9
Durometer Hardness	D 80
Density	1.34
ELECTRICAL PROPERTIES	
Dielectric Strength, v/mil	4250
Volume Resistivity, ohm-cm	1.1×10^{13}
Dielectric Constant	3.88
Power Factor	0.75
THERMAL PROPERTIES	
Melting Point, F	350
Softening Point, F	180
Service Temperature Range, F	−40 to 220

Properties

Goodyear says the film can be used over a temperature range of −40 to 220 F. A low elongation value of approximately 4% has been deliberately engineered into the product in order to achieve maximum abrasion resistance, good forming and stretch laminating properties, and good weathering characteristics.

Various laboratory and field tests indicate that the laminating film has good weather resistance. For instance, the plastics film has been exposed in a Weatherometer for 200 to 300 hr, in a Fadeometer for 300 to 600 hr, and in salt spray for 800 to 1000 hr without any noticeable change taking place. The film did not discolor or crack after one year exposure in Arizona and Florida.

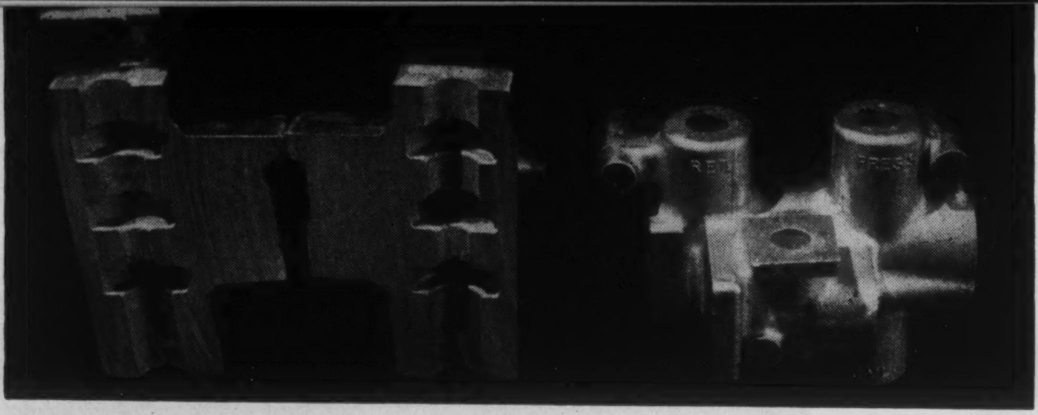
Tests also show Videne A has good resistance to such solvents as carbon tetrachloride, gasoline, methyl ethyl ketone, benzene, ethyl alcohol and diethyl ether. The film swells 0.4 to 0.5% in water and 1.0 to 1.5% in SAE oil after 24 hr at 77 F.

Formability

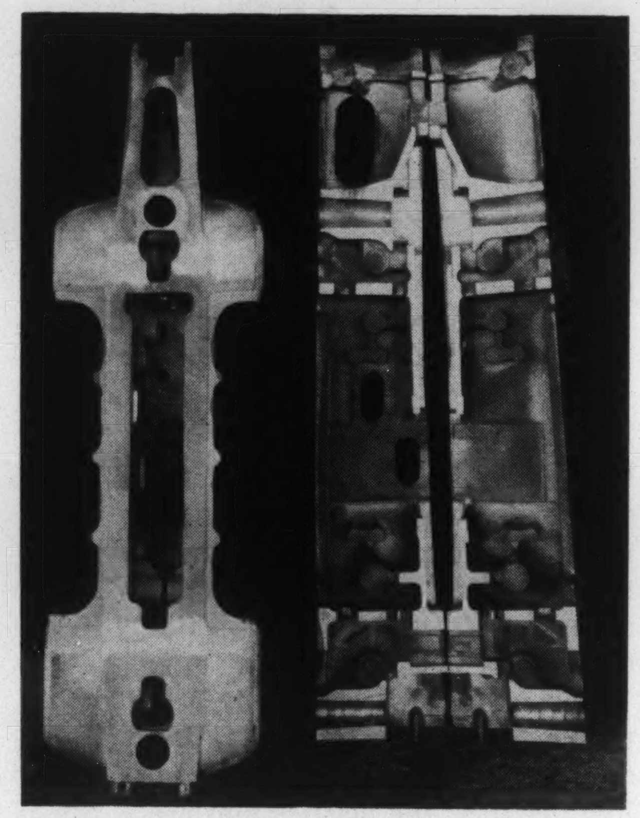
The polyester film can be vacuum formed on conventional equipment at temperatures of 200 to 300 F. It can be laminated to various materials at temperatures of 275 to 325 F and pressures of 10 to 100 psi, depending on final density required. The film can be embossed, metallized and printed.

(more What's New on p 142)

◄ For more information, circle No. 382



***Hydraulic valve** operating at high pressure is permanent mold cast of aluminum alloy Tens-50.*



***Three-part molds** are needed to cast this large pylon, yet the rejection rate is extremely low.*

Castings of New Aluminum Alloy Almost As Strong As Forgings

■ A new aluminum alloy is said to be capable of being cast with strength approximately equal to that of some forged parts. The new alloy, called Tens-50 and developed by Navan Products, Inc., Santa Monica, Calif., is also said to represent a new approach to alloying for higher strength casting. According to Navan, beryllium and sodium are used to neutralize the embrittling effect of iron and sodium, and consistent results are practically ensured.

Specific details of the new alloy's composition have not been revealed. However, the producer says that the new alloy is exceptionally free-flowing and can be used to cast complicated designs by both sand and permanent mold methods with a minimum of rejection rates. A typical permanent mold casting, a valve subject to 7500 psi internal pressure, withstood 10,000 psi with no failure; the same part cast of 356 aluminum alloy, burst at 5600 psi.

Strong at high temperatures

Although the new alloy is specifically designed for high strength at room temperature, relatively good properties are observed at elevated temperatures. At 400 F, for example, the ½-hr curve for Tens-50 sand castings reveals a tensile strength of 30,000 psi and a yield strength of 25,000 psi, as compared to 23,000 psi and 19,000 psi for the 356-T6 alloy. When exposed to 400 F for 10 hr, the new alloy is said to retain the following percentages of room temperature properties:

Sand castings	
Tensile strength	62%
Yield strength	72%
Permanent mold castings	
Tensile strength	72%
Yield strength	72%

Mechanical properties and suggested design minimums of Tens-50 sand and permanent mold castings, and a comparison of properties of forgings and castings are given in the accompanying tables.

FORGINGS VS CASTINGS—A COMPARISON OF PROPERTIES

	Ten Str, 1000 psi	Yld Str, 1000 psi	Elong, %
Forgings			
2014-T6	65	55	10
6061-T6	38	35	10
PERMANENT MOLD CASTINGS			
Tens-50-T6	**45**	**38**	**3**
356-T6	33	22	3
SAND CASTINGS			
Tens-50-T6	**42**	**32**	**3**
356-T6	30	20	3

MECHANICAL PROPERTIES OF TENS-50 ALUMINUM ALLOY

Type of Casting ➡	Sand		Permanent Mold	
	Typical	Suggested Design Minimum	Typical	Suggested Design Minimum
Tensile Strength, 1000 psi	46	42	50	45
Yield Strength, (0.2% offset), 1000 psi	36	32	44	38
Compr Yield Strength (0.2% offset), 1000 psi	36	32	41	38
Shear Strength, 1000 psi	41	35	44	38
Bearing Strength (e/D= 2.0), 1000 psi	98	88	103	94
Bearing Yield Strength (e/D = 2.0), 1000 psi	62	56	73	67
Elongation (in 2 in.), %	5	3	6	3

Available as molded and formed parts . . .

Insulation Has Radically Low Thermal Conductivity

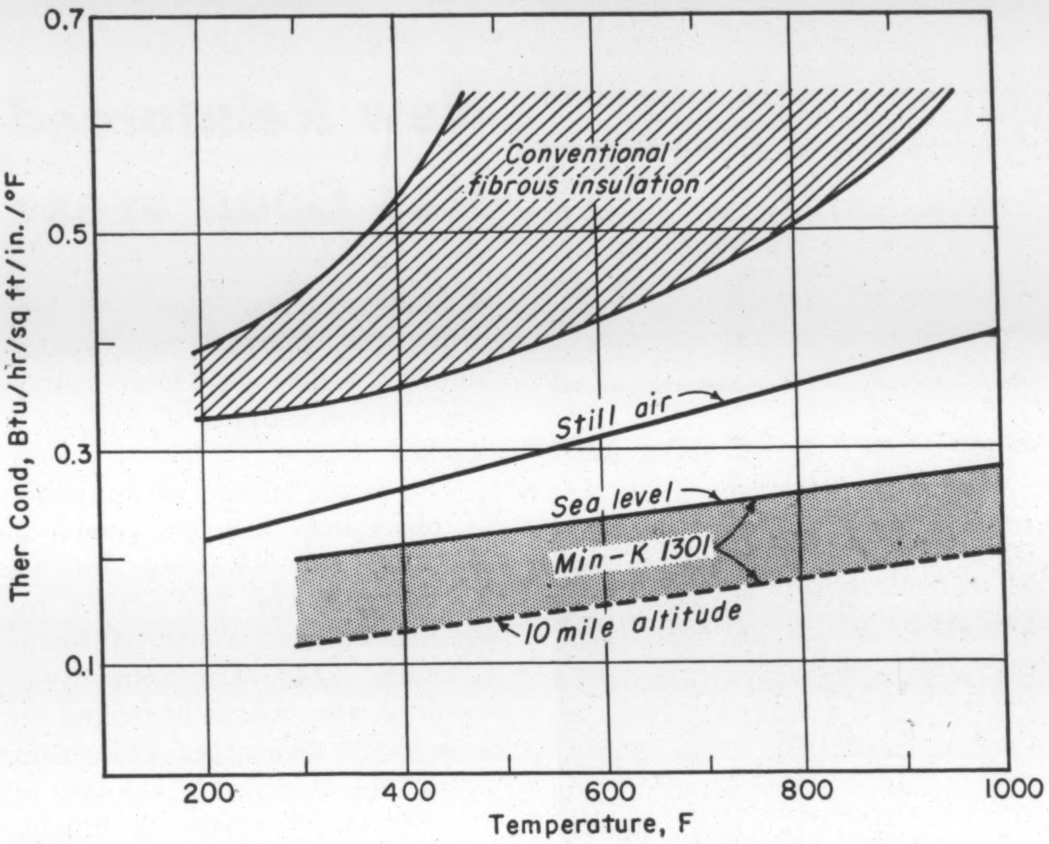
■ A new family of thermal insulations is now available as custom molded and formed parts from Johns-Manville Corp., 22 E. 40th St., New York City. Called Min-K, the new type of insulation is said to have a thermal conductivity well below the conductivity of still air. It is designed especially for use in high speed aircraft and missiles but can also be used in industrial and nuclear applications.

Although the company has not revealed the composition of the insulating material, it does say that it is a ". . . nonmetallic inorganic material composed of silica, asbestos and other materials." It is also described as ". . . a bonded structure reinforced with fibrous media and containing appreciable quantities of particle matter, the ultimate structural elements of which are exceedingly small."

The small elements that comprise the insulation are said to create minute pores in the structure which permit a large proportion of gas molecules to collide with the wall of the structure rather than with other molecules. Thus, the amount of heat transferred by molecular gas conduction (heat transference by collisions or interactions between air molecules having different energies) is reduced considerably below that which would occur in a still air space. In addition, opaque media contained in the material effectively minimizes the transmission of radiant heat energy through the insulation.

Missile, jet uses

According to the producer, the insulation could conceivably increase the fuel capacity of a rocket or a missile by as much as 20%, since it can perform the same job of insulating in one-third the space required by conventional fibrous insulations. The thermal conductivity of Min-K is said to decrease appreciably at lowered atmospheric pressures and consequently at higher altitudes. For instance, at an altitude of 10 miles, which is a typical flying range for many rockets and missiles, the thermal conductivity of the insulation decreases by as much as 50%, with correspondingly larger reductions taking place at higher altitudes.



Thermal conductivity: *Min-K 1301 vs conventional fibrous insulation.*

Five types available

Five types of Min-K insulation are available: four comprising the 500 series for temperatures up to 500 F, and one (so far) comprising the 1300 series for temperatures up to 1300 F. One insulation, Min-K 1301, is expected to have a wide range of uses in the guided missile field. It can be used for extended periods of time at temperatures up to 1300 F, it has high strength, it has good resistance to vibration, it is relatively easy to handle, and it can be formed to comparatively close dimensional tolerances.

Johns-Manville engineers say the family of insulations could be furnished in combination with a reinforced plastics laminate for use in guided missile applications where thermal exposures are usually restricted to a matter of minutes. (For comparative information on conventional thermal insulations, see MATERIALS IN DESIGN ENGINEERING, Mar '58, p 119.)

(more What's New on p 144)

PROPERTIES OF MIN-K INSULATIONS

Type ➡	501	1301
PHYSICAL PROPERTIES		
Density, lb/cu ft	10	20
Transverse Strength, psi	4	75
Compressive Strength, psi		
5% Compression	16.5	94
10% Compression	32.5	200
Linear Shrinkage, %	Nil	1
Min Thickness, in.	¼	⅛
THERMAL PROPERTIES		
Max Service Temp, F	500	1300
Ther Cond, Btu/hr/sq ft/in./°F		
200 F	0.14	—
400 F	0.16	0.21
600 F	—	0.23
1000 F	—	0.27

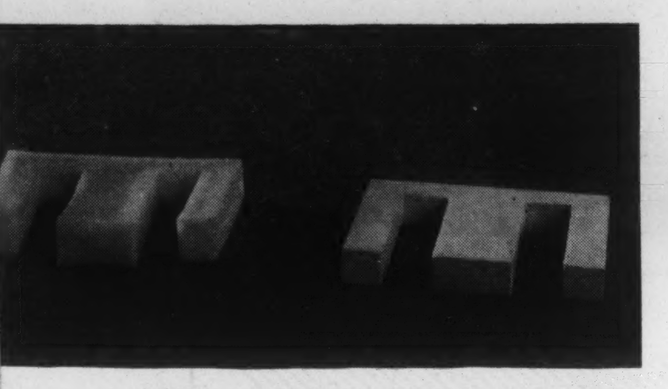


Fig 1—Effect of thermal shock on Fluorosint (right) and unmodified TFE (left). Parts were heated to 700 F, then quenched in water.

New Reinforced TFE Resin Has Good Wear Resistance

■ Reinforcement seems to improve the thermal and dimensional stability and wear resistance of unmodified Teflon to a marked degree.

This is the opinion of a number of observers (see MATERIALS & METHODS, Nov '55, p 110; Jan '57, p 148; and Apr '57, p 135) including Polymer Corp. of Pennsylvania, 2140 Fairmont Ave., Reading, Pa., which has come up with a new reinforced TFE resin exhibiting, it says, ". . . a two to fourfold improvement in dimensional tolerances of molded parts over unmodified TFE." The company calls its reinforced TFE resin Fluorosint and is making it available in pilot plant quantities as molded parts, rods, bars and tape.

Other improvements

Polymer Corp. has not revealed what the reinforcement in Fluorosint is but says: "The addition of the high temperature inorganic reinforcing agent used in Fluorosint has a negligible effect on dielectric strength, surface resistivity and density."

Other major property improve-

(continued on p 146)

This article is based on a paper by Ralph E. James, Jr., vice president, Polymer Corp. of Pennsylvania.

How wear test was run

See p 152

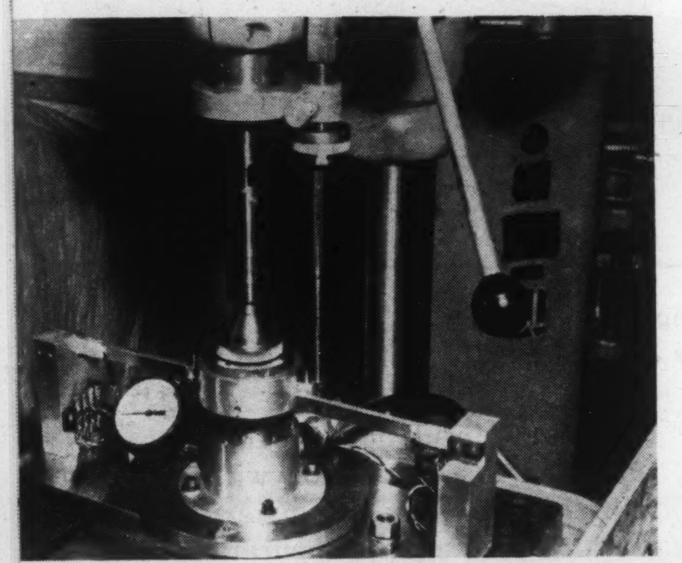


Fig 2—Assembled bearing tester showing spindle, sample holder and spherical air bearing in operating position. The deflection of the horizontal arms is measured by strain gages and recorded as coefficient of friction.

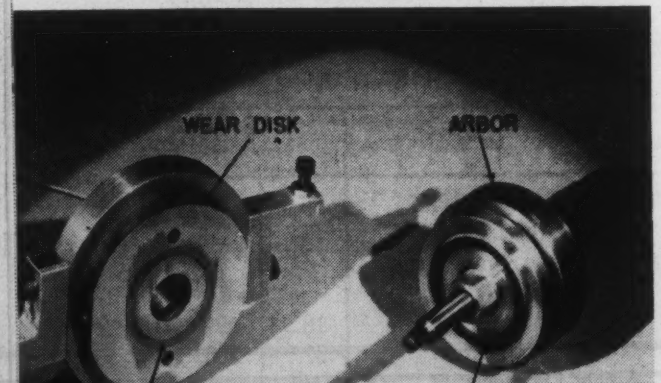


Fig 3—Disassembled wear disk and sample holder as they appear at the end of a run. The wear track on the disk (left) is a plating of nylon which occurs at failure conditions.

BEARING CHARACTERISTICS OF FLUOROSINT

PV[a]	Load, psi	Speed, rpm	Coef of Friction	Wear Rate, mil/hr	
				1st Hr	Overall
500	6.0	83.3	—	—	—
990	11.9	83.3	0.12	0.1	<0.1[b]
4,950	59.5	83.3	0.16-0.19	0.1	<0.1[b]
10,000	120.5	83.3	0.20-0.30	0.5	<0.1[b]
15,000	98.5	152.0	0.34-0.40	<0.1[b]	<0.1[b]
20,000	131.5	152.0	0.34-0.42	4.0	0.8

[a] Load per sq in. of bearing area times velocity in ft per min.
[b] Wear rates were too small to record on the equipment.

MORE WHAT'S NEW IN MATERIALS

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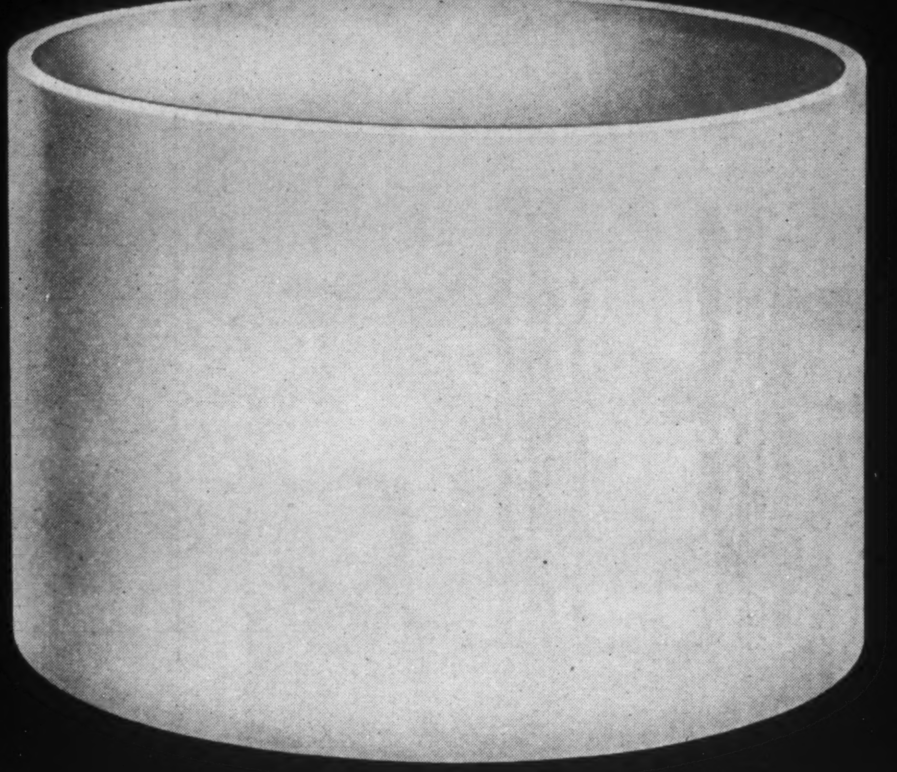
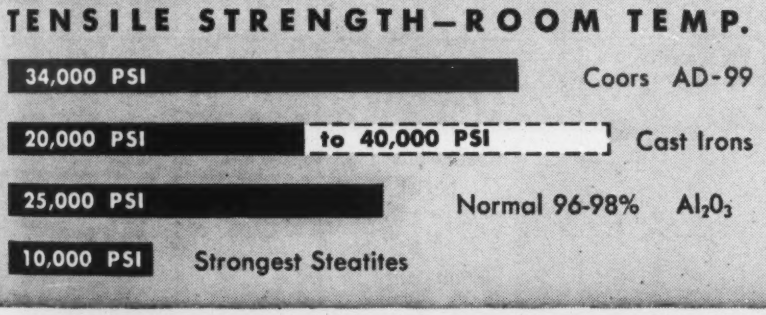
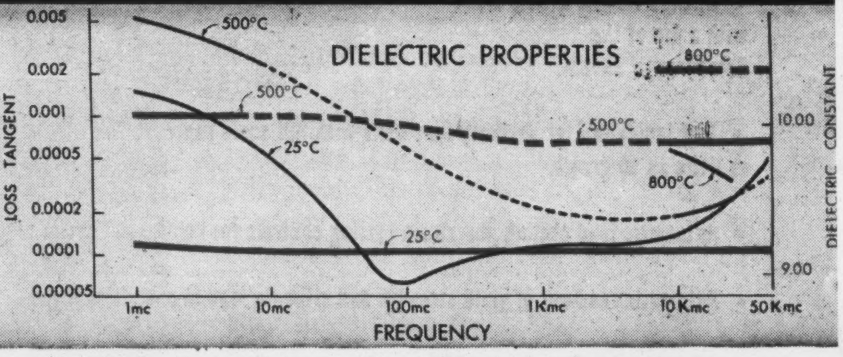
Coors NEW AD-99 ALUMINA CERAMIC



AD-99 Ceramic Tube Envelope 10" dia. x 3"





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Coors new AD-99 ceramic is nonporous 99.0% Al_2O_3 with the amazing tensile strength of 34,000 psi — as strong as cast iron. It has 30% greater strength than the best commercial high aluminas of 96% to 98% Al_2O_3. It is particularly superior to any ordinary metals in strength at high temperatures —retaining 75% of its tensile strength or 20,000 psi at 2000°F (1100°C).

Coors AD-99 is a superior dielectric material. At modern micro-wave frequencies, loss tangents are lower than those of plastics and all but one or two special ceramic materials—as reported by the Laboratory for Insulation Research, Massachusetts Institute of Technology. At room temperature, the loss tangent is 0.00006 ± 0.00002 at 100 mc, less than 0.0001 at 300 mc, and 0.00052 at 50 Kmc.

These properties, combined with the excellent hardness and wear resistance of the alumina family, make this the most superior ceramic now available for commercial use. In addition, Coors AD-99 has complete, unequaled homogeneity made possible only through the use of the Coors isostatic process.*

Originally developed in Coors own laboratory especially for radome work, Coors AD-99 is now available on a commercial production basis for critical electronic and mechanical applications. We can make test parts for your developmental work at nominal costs. Production quantities can be supplied at prices only slightly higher than ordinary alumina ceramics.

**Coors Porcelain Company operates under license for this patented process from Champion Sparkplug Company, Toledo, Ohio.*

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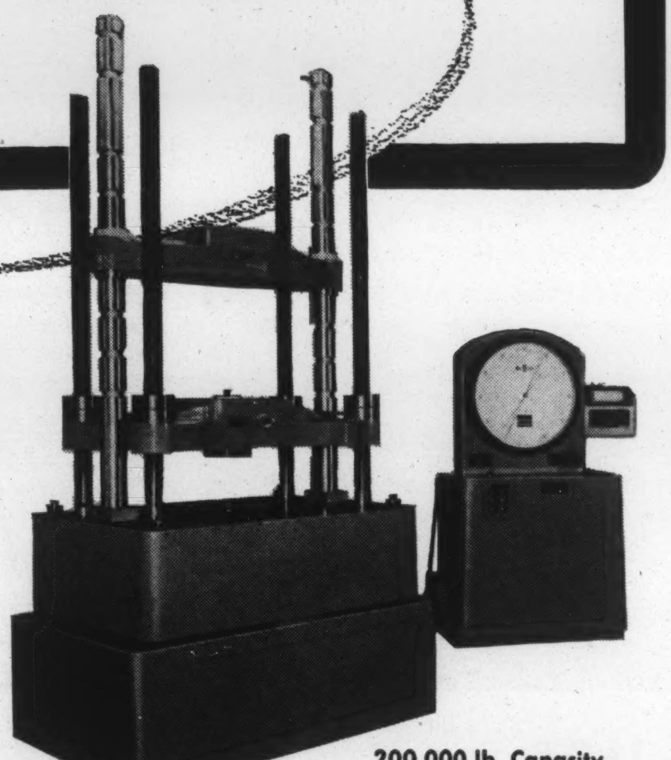

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ments obtainable with Fluorosint parts are:

1. A coefficient of thermal expansion one-sixth that of unmodified TFE—closely matching the coefficients for aluminum, brass and most nonferrous alloys.

2. Three to four times the creep resistance of unmodified TFE, even at temperatures above 350 F.

3. Good dimensional stability when heat cycled. Fluorosint parts heated to 700 F can be quenched in cold water with negligible change in dimensions (see Fig 1).

Potential uses

Fluorosint is said to be particularly useful as an unlubricated bearing material for fractional horsepower motors, instruments and electric shavers. For instance, a Fluorosint sleeve bearing has operated successfully for four

PROPERTIES OF FLUOROSINT[a]

	Unmodified TFE	Fluorosint
PHYSICAL PROPERTIES		
Specific Gravity	2.1-2.2	2.3-2.4
Coef of Ther Exp, per °F		
70 Hr at 140 F	6.9×10^{-5}	1.1×10^{-5}
70 Hr at 500 F	9.7×10^{-5}	1.7×10^{-5}
Flammability, in./min	Does not burn	Does not burn
Molding Tol., in./in	±0.006-0.010	±0.003
Dimen. Chg After Quenching at 700 F	Very Large	Negligible
MECHANICAL PROPERTIES		
Ten Str, psi	1500-3000	700-1500
Elongation, %	75-350	10-200
Durometer Hardness	D 50-55	D 70-75
Def. Under Load (1200 psi), %		
24 Hr at 300 F	14-18	3-5
24 Hr at 400 F	22-30	4-7
ELECTRICAL PROPERTIES		
Dielec Str, v/mil	450-500	450-500
Vol. Res, ohm-cm	10^{15}	10^{15}
Dielec Const ($60-10^9$ cps)	1.9-2.1	2.9-3.1
Dissip Factor ($60-10^9$ cps)	<0.0003	0.0003-0.0005

[a] A spread in values indicates normal property variations on molded items.

Tool Steel Topics

BETHLEHEM STEEL

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Brake Die saves shop time in forming overlap for steel spout

he problem sounded simple enough — utting an overlap in a section of 20-age stainless steel, which was then ormed into a spout for use in meat-ackaging tables. But getting a tool steel hich could do the job more economically han the grade formerly used was some-hat of a challenge for the manufacturer, . B. Dove & Sons, Inc., Philadelphia.

The answer was Bethlehem Brake Die, upplied by our local tool steel distribu-or, Hill-Chase & Co. Because of Brake ie's easy machinability and good wear-esistance, the new die minimized manu-acturing costs. It also helped in pro-ucing a better-looking product. Said ne of the Dove engineers: "We like Brake Die. It's doing a good job for us."

Brake Die, a special alloy steel, is oil-quenched and tempered to develop a fine balance of mechanical properties. It's ideal where wear-resistance, toughness, resistance to impact and good machin-ability are required.

Typical Analysis

Carbon 0.50	Manganese 0.90
Chromium 1.00	Molybdenum 0.20

Chances are there might be one or more applications in your shop right now where Brake Die steel could be used to good advantage. Why not talk it over with your Bethlehem tool steel distributor?

BETHLEHEM TOOL STEEL ENGINEER SAYS:

How to Shrink-Fit Tool Inserts

Shrink-fitting of tool steel inserts is a procedure which is being widely used to improve the service life of tools. Shrink-fitting is most applicable to rings and cylinders, such as are used in heading and drawing operations where the tools can be shrink-fitted into large retaining rings. The shrink-fit sets up radial compressive stress in the tool, which is available to oppose radial tensile stress set up in service, and thereby improves the performance as compared to solid tools which are not pre-stressed. Shrink-fitting of tools should be carried out as follows:

1. The retainer must be of adequate diameter and strength to provide the stresses required on the tool insert. This generally means that an alloy steel capable of hardening to approximately 300/400 BHN must be used. Shock-resisting tool steels heat treated to approximately Rockwell C 48 to 52 are used on heavy duty applications. It is recommended that the OD of the retainer be a minimum of twice the ID (preferably three times the ID).

2. A shrink-fit allowance of .003/.004 in. per in. should be provided for. This means that the OD of the insert is .003/.004 in. per in. larger than the ID of the retainer into which it must fit. These dimensions must be carefully maintained in order to obtain the benefits of shrink-fitting.

3. The OD of the insert and the ID of the retainer should have a smooth finish, preferably produced by grinding.

4. The retainer should be heated to a temperature sufficient to cause the expansion necessary to assemble the insert. Care should be exercised not to exceed the tempering temperature used in heat-treating the retainer. If necessary, the insert may be sub-zero cooled to aid in providing the clearance required for assembly.

5. After assembly of the parts, cooling of the assembly should be rapid enough to prevent over-tempering of the insert by heat transferred from the retainer.

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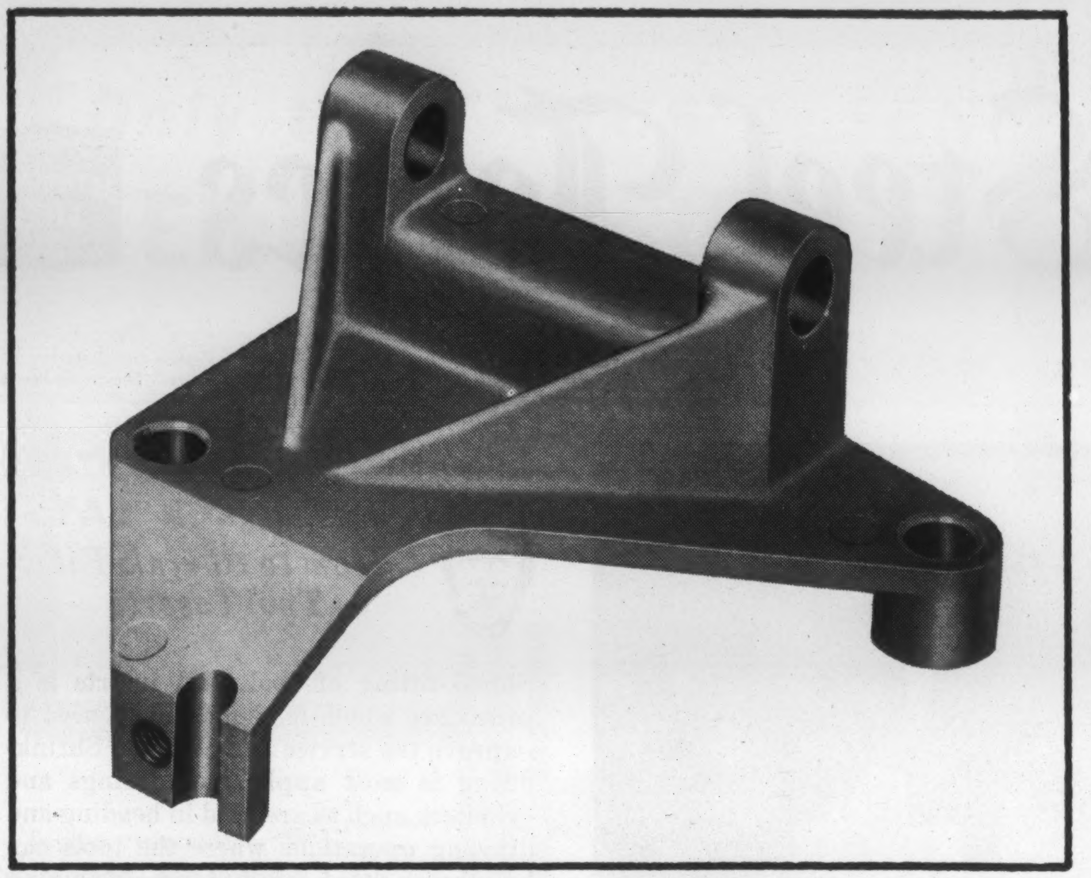

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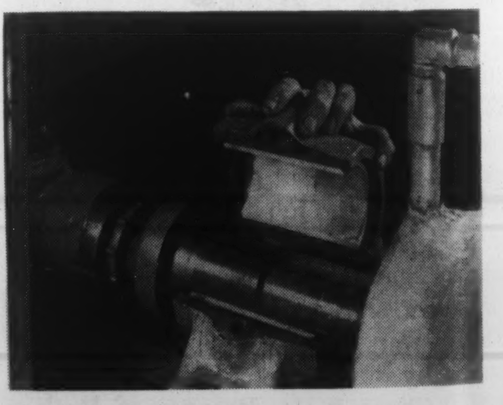
months on a 24-hr basis at 450 F without failure. In addition, the new material can be used as a bearing material for a variety of chemical and plating equipment.

Fluorosint parts should be useful on conveyors, sliding doors and other devices where long wear surfaces are involved. The reinforced TFE resin also has potential use as seals, gaskets, valve seats, pistons and piston rings. Because Fluorosint is sometimes microscopically porous, there is some question about its use where absolute seals are required, particularly where gases are involved. Modifications are being developed which are expected to overcome this difficulty.

The reinforced TFE resin may turn out to be a good insulating material for panel boards, cables, connector inserts and tube sockets. Fluorosint's good electrical properties, combined with its good bearing characteristics and dimensional stability, make it an interesting material for switchgear components, rotating and sliding electrical parts, and bushings and bearings in electric motors.

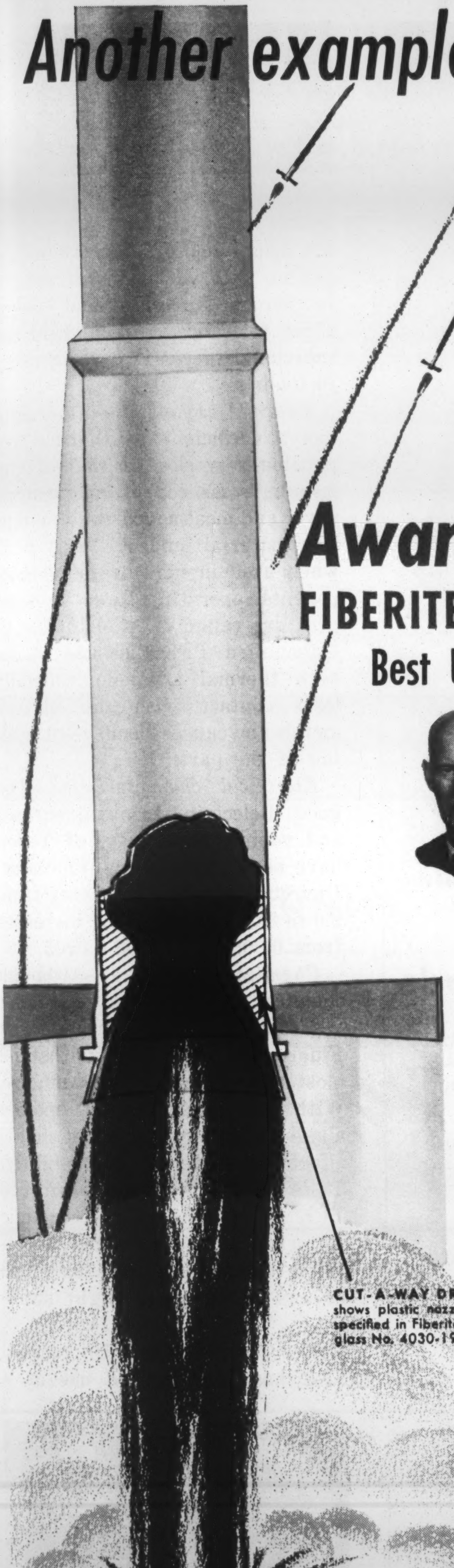
Properties

Dimensional stability—The chief advantage of Fluorosint is its ability to be molded to close dimensional tolerances. According to the producer, run-of-the-mill tolerances for Fluorosint parts



Fluorosint bearing *as it looks after four months of continuous operation at 450 F. Galling of the shaft resulted from failure of metallic bearings used previously.*

Another example of FIBERITE at work...



Award Winner!

FIBERITE Phenolic Glass Helps Win an Award for Best Use of Materials in Product Design

Paul T. Barnes, Mechanical Engineer, is winner of an M/DE award for his redesign of the "Lar" rocket exhaust nozzle. The nozzle section is molded of Fiberite No. 4030-190. Mr. Barnes says: "In arriving at the use of the Fiberite material many things were tested over nearly a year's time. Fiberite satisfied our requirements. In addition to satisfying application requirements Fiberite also lowered the cost."

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CUT-A-WAY DRAWING shows plastic nozzle section specified in Fiberite phenolic glass No. 4030-190.

PRODUCT DESIGNER: Paul T. Barnes working with Weapons Development Dept. of the U.S. Naval Ordnance Test Station, China Lake, Calif.

MOLDER: Lee Deane Products, Norwalk, Calif.

MANUFACTURER: Los Angeles Automotive Works, Los Angeles, Calif.

MOLDING COMPOUND: Fiberite No. 4030-190, chopped glass fiber impregnated with phenolic base resin, designed to meet government specifications MIL-M-19536.

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THE FIBERITE CORPORATION
Manufacturers of Plastic Molding Compounds
Main Office: WINONA, MINNESOTA Phone 2316

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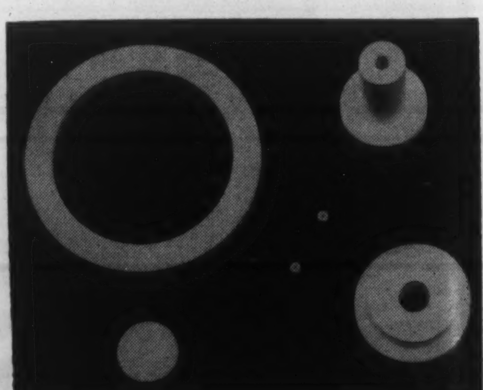
are usually closer than ±0.003 in. per in. with variations of ±0.001 in. per in. for individual pieces. Close tolerances can be held for individual pieces if care is taken in tooling.

Thermal expansion—Fluorosint has a coefficient of thermal expansion very close to that of aluminum, brass, copper, magnesium, silver and most nonferrous metals. The material tends to "stay put" when used in mating metal components operating over a temperature range of –450 to 550 F. Unmodified TFE, because of its high thermal expansion, usually loses contact with the mating metals and causes insufficient sealing of the part.

Electrical characteristics—The good dielectric strength, surface and volume resistivity, of Teflon have been retained in Fluorosint. Dielectric constant increases from 2.0 to 3.0 and loss factor increases from 0.0002 to 0.0003-0.0005.

Chemical resistance—Although chemical resistance tests are not yet complete, it is expected that Fluorosint parts will withstand most acids other than hydrofluoric. With the exception of molten alkali metals, strong bases should affect the material only slightly. Tests to date show the reinforced TFE is unaffected by organic materials other than a few fluorinated compounds such as some Freons which cause slight swelling.

Wear resistance — Unmodified TFE has very limited use as a



Typical parts *molded from Fluorosint reinforced TFE resin.*

Shown 1/18 actual size

How missile designers can use
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Shown here are a few shapes, shells and missile components produced at production-line speed by *Hackney Deep Drawing Methods.* They were designed to reduce weight without sacrificing strength, save production or assembly time, and lower costs.

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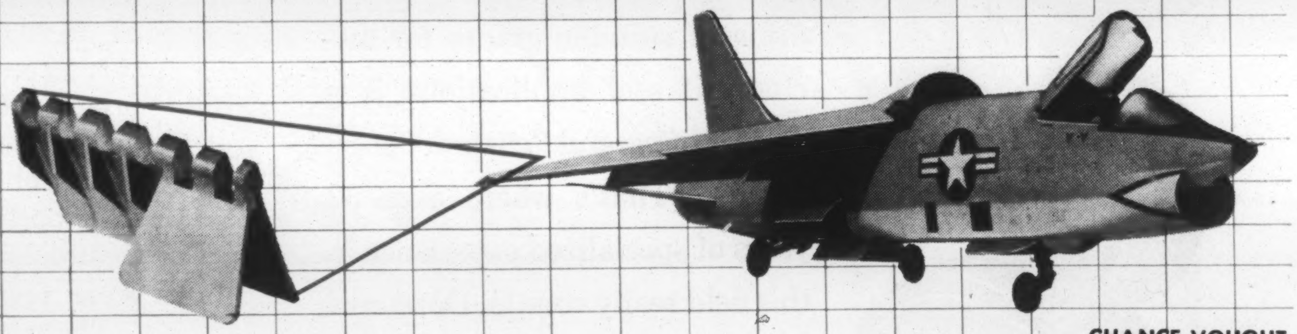

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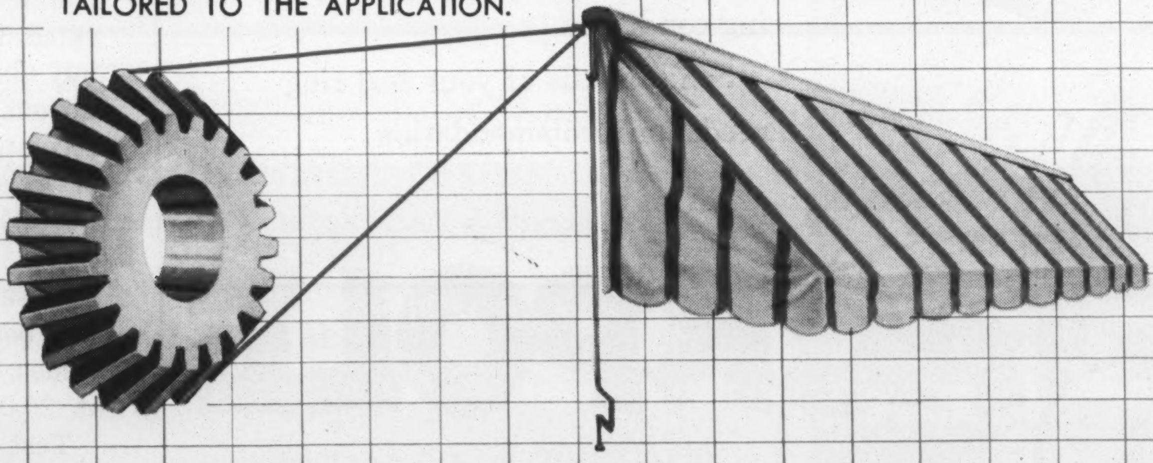

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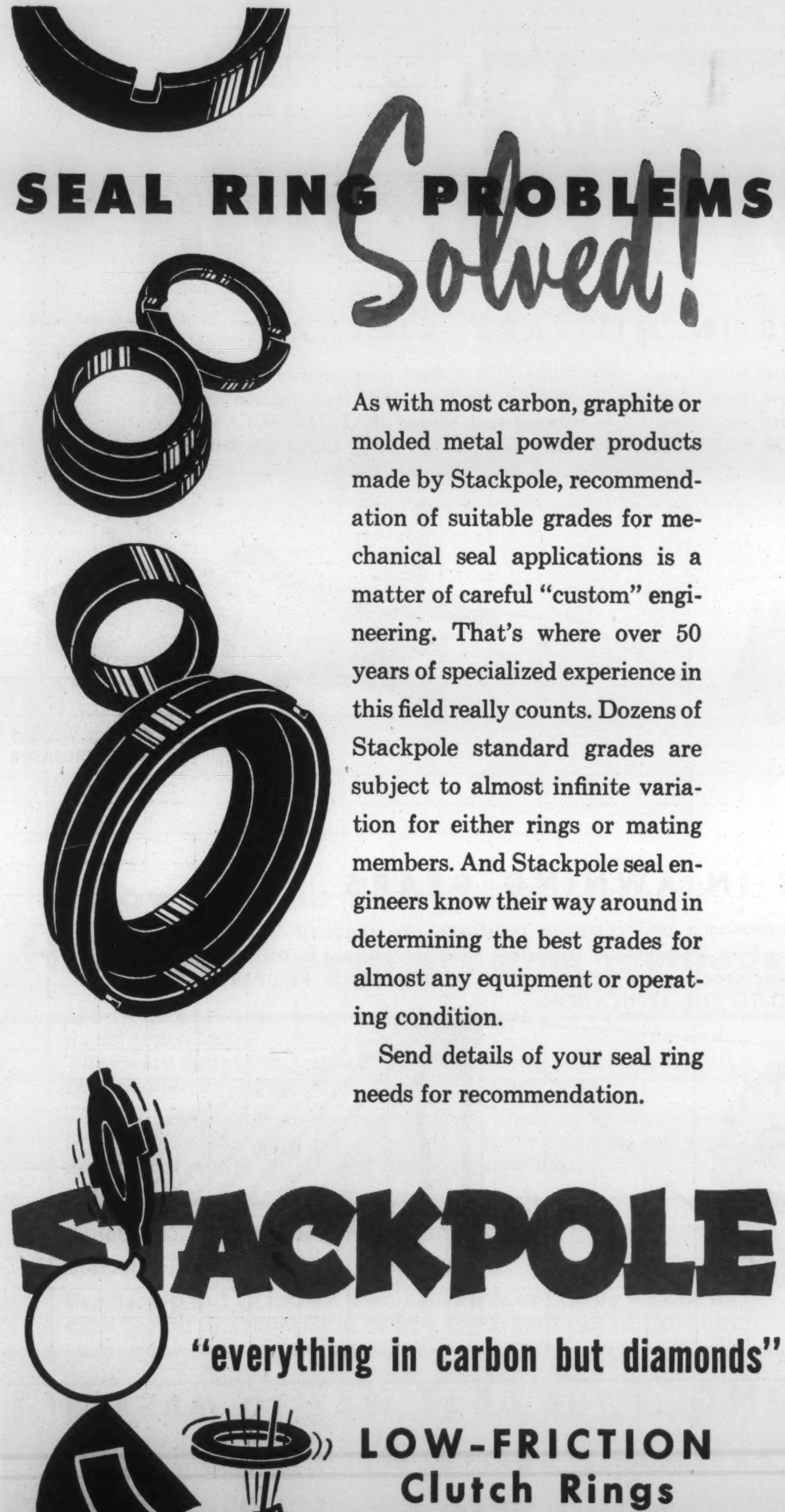

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St. Marys, Pa.

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bearing material because it wears rapidly at ordinary speeds and loads. Fluorosint, on the other hand, while retaining the slippery feel and low coefficient of friction of unmodified TFE, has good wear resistance and can be used as an unlubricated bearing at PV values (load per sq in. of bearing area times velocity in ft per min) of 15,000 to 20,000. This value corresponds to that for oil-impregnated porous bronze bearings and is about 10 times higher than values obtained with nylon bearings operating in the same test fixture.

Wear tests

The wear resistance of Fluorosint, nylon and unmodified TFE was investigated by Polymer Corp. engineers in a thrust bearing testing device shown in Fig 2 and 3 (p 144). The three materials were molded into thin-walled washers and run against a ground steel plate.

The test shows that the useful range for nylon as an unlubricated bearing is below 5000 PV but above 1000 PV. Failure conditions in nylon bearings were accompanied by a heavy plating of nylon on the wear plate (see Fig 3). Unmodified TFE wears quite rapidly at 500 PV and is not usable at a PV of 5000. Fluorosint bearings perform well to PV values of 15,000 but wear rapidly at 20,000.

Test results show that the bearings undergo a break-in period at the start of the test; a bearing often had 0.0001 to 0.0005 in. of wear during the first hour of a test series.

Fabrication

The reinforced TFE resin is molded using techniques akin to those employed in powder metallurgy. Undercuts, radial holes and the like are difficult or impossible to mold. Overall size of pieces is presently limited to 4 sq in. in cross section and 2 to 3 in. in length. Larger parts, or those

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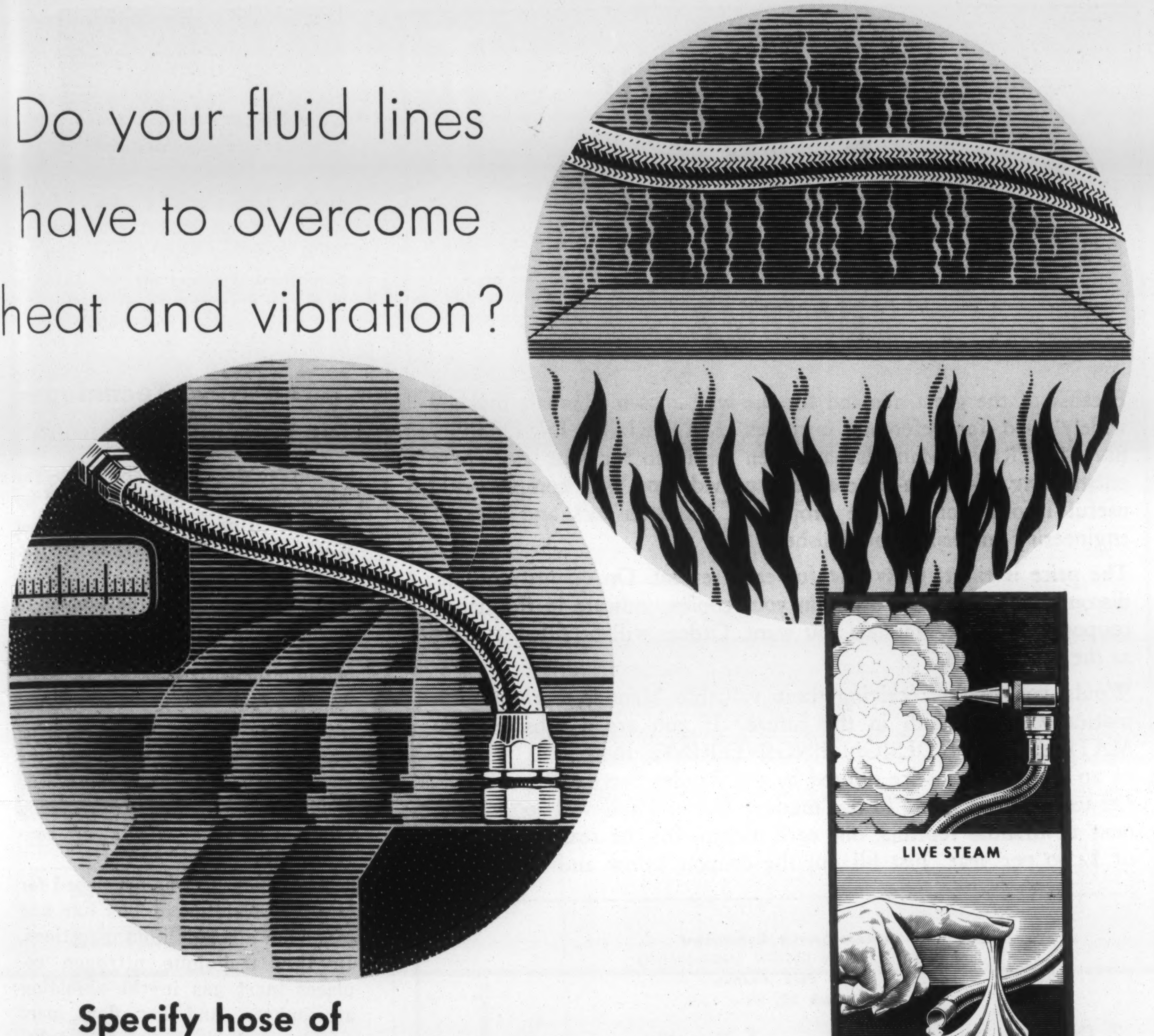

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*TEFLON *is Du Pont's registered trademark for its fluorocarbon resins, including the TFE (tetrafluoroethylene) resins discussed here.*

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which do not lend themselves to TFE molding techniques, can be machined from rods or tubular bars, or stamped from strip.

Three New Techniques for Welding Aluminum

Three welding techniques for aluminum have been developed by Kaiser Aluminum & Chemical Corp., Kaiser Bldg., 1924 Broadway, Oakland 12, Calif.

1. *Qualiweld* was developed to produce consistently high quality welds by reducing porosity and dross. In this process an MIG welding gun is modified so that a mixture of argon and chlorine gases can be introduced down the contact tube directly into the inner core of the arc, thereby eliminating the effects of contaminants.

2. *Econoweld* was developed for low cost welding of bus bar and other low alloy aluminum sections. In this technique nitrogen replaces inert gas in the shielding atmosphere, and low flow inert gas is used in the contact tube.

3. *Chlorecon* was developed for low cost welding of all weldable aluminum alloys. This technique employs a low flow of inert gas, such as argon containing a small amount of chlorine, down the contact tube with a low flow of inert gas through the nozzle in the outer shield.

Clear Packaging Tape Is Easy to Apply

A general purpose pressure sensitive tape, said to be resistant to many acids, moisture, alkalis and solvents, has been introduced by Minnesota Mining & Mfg. Co., 900 Bush St., St. Paul 6, Minn.

Called Scotch brand Paklon No. 681, the tape is transparent, nonflammable and printable. It has

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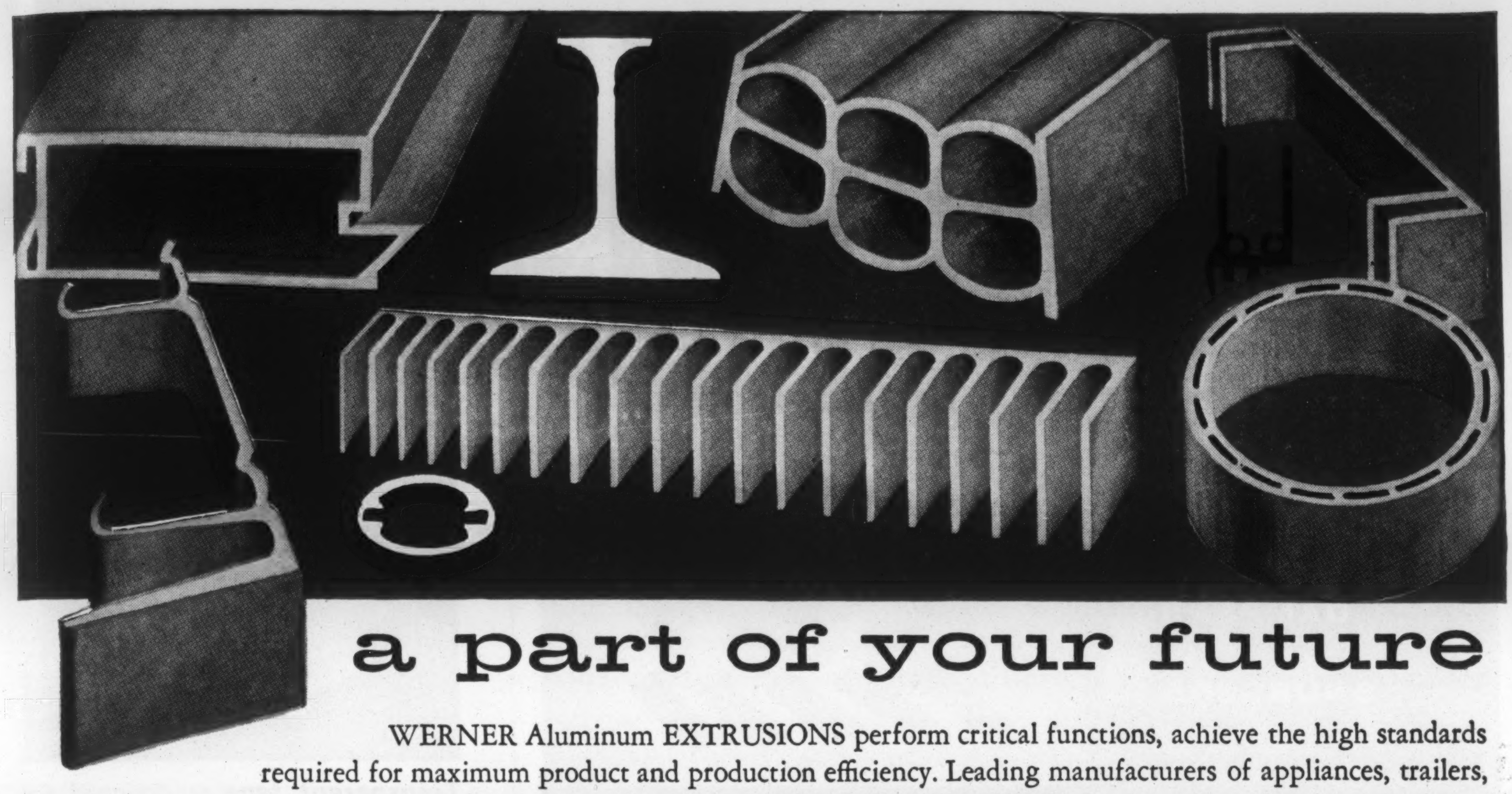

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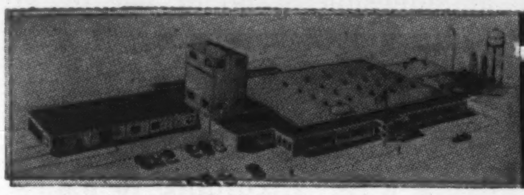
WERNER Aluminum EXTRUSIONS perform critical functions, achieve the high standards required for maximum product and production efficiency. Leading manufacturers of appliances, trailers, curtain walls, aircraft, etc. depend on WERNER EXTRUSIONS for precision tolerances, consistent quality control and delivery to meet their production schedule. If your present or future product requirements include extruded aluminum parts—contact WERNER Aluminum. *Sales representatives located in principal cities.*



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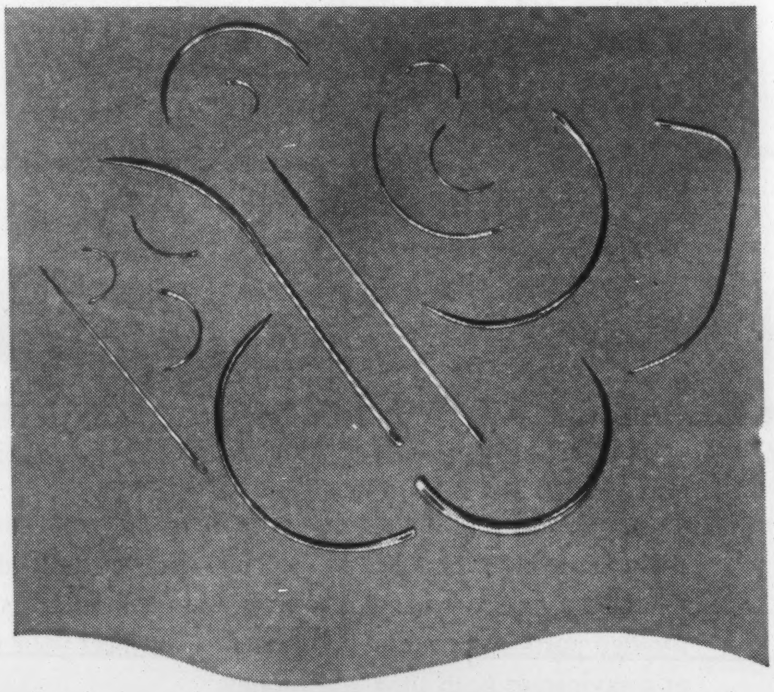

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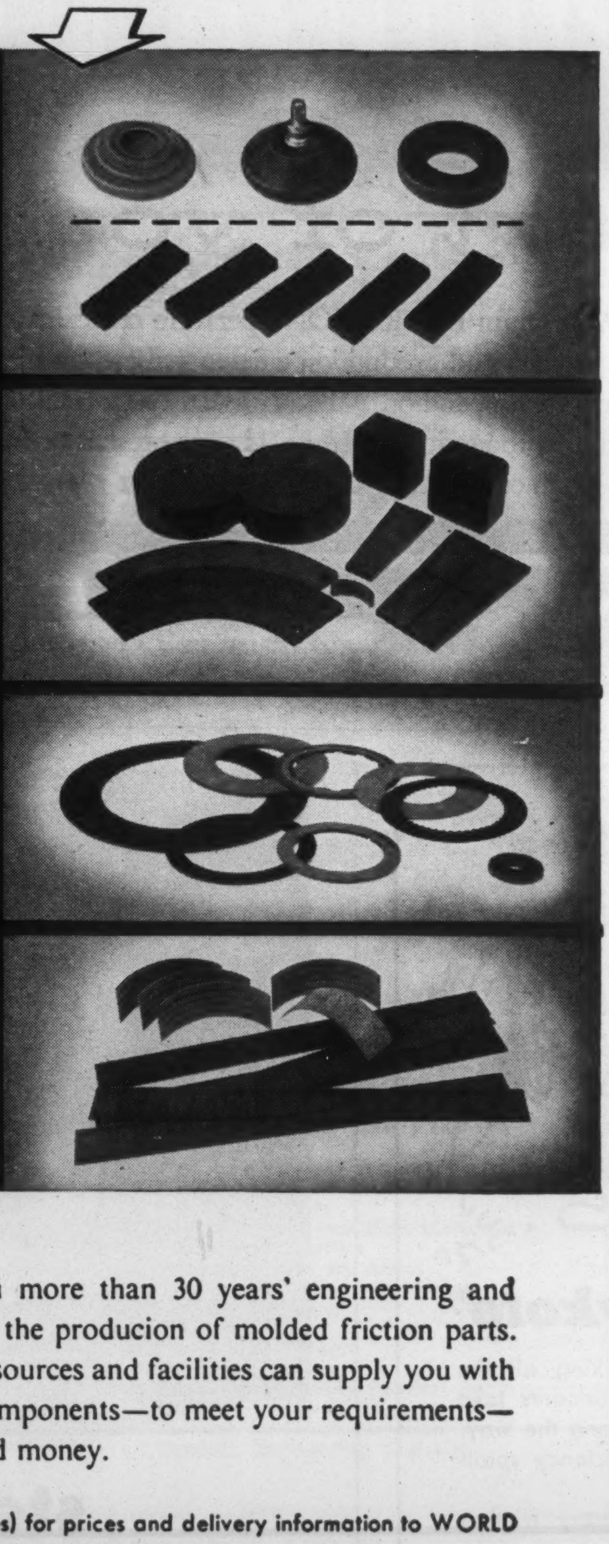

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What's new IN MATERIALS

***Transparent tape** is designed for industrial packaging.*

an adhesion of 40 oz per in. of width and a tensile strength of 25 to 35 lb per in.

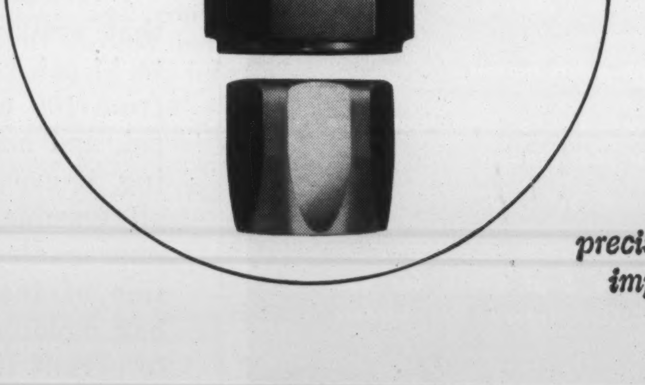
The tape is recommended for light to medium industrial packaging uses. According to 3M, a special treatment on the tape permits the user to remove it easily from the roll.

Phenolic Laminates Hold Up at 500 F

A demand for more heat resistant plastics aircraft parts than presently available has resulted in the development of a new heat resistant phenolic laminating resin and an asbestos-base phenolic laminate. The resin was developed by Barrett Div., Allied Chemical and Dye Corp., 40 Rector St., New York City, and the laminate was developed by Continental-Diamond Fibre Corp., Newark, Del. Both the resin and the laminate have good high temperature properties (500 to 600 F) and are particularly suited for use in missile and aircraft parts.

Interest in reinforced phenolic aircraft parts has been growing ever since the operating temperatures of aircraft have been increasing beyond the capabilities of glass-reinforced polyester parts. (For more detailed information

ARE ALUMINUM COLD FORGINGS ECONOMICAL ONLY ON COMPLEX DESIGNS?



Nipple, nut and socket of Aeroquip Detachable and Reusable Fittings for flexible hose lines currently used in piston and jet aircraft plumbing. Four sizes from 1" through 2" are available.

The answer is NO! Here's a typical product relatively simple in design and with no unusual production problems. Originally turned from solid bar stock, the components were later made from hot forgings.

With a wide-awake eye to costs, Aeroquip management investigated Hunter Douglas aluminum cold forgings. Now completely cold forged from 2014-T6 aluminum alloy, these components not only prove more economical dollar-wise, but have eliminated a costly inventory problem! Shipments are now met promptly *with less money tied up in stock* because of Hunter Douglas' ample production capacity and rapid delivery schedules. In addition, product quality with the aluminum cold forgings has noticeably improved.

Get full details on Hunter Douglas Aluminum Cold Forgings

If your components can benefit by *high strength, precision tolerances, absence of porosity, zero draft* and *improved surface finishes,* investigate Hunted Douglas Aluminum Cold Forgings! A comprehensive treatise is available to letterhead requests. Write for "The Story Of Aluminum Cold Forgings."

Hunter Douglas HD Aluminum

DIVISION OF BRIDGEPORT BRASS COMPANY • Dept. MDE-5, 3016 Kansas Avenue, Riverside, California

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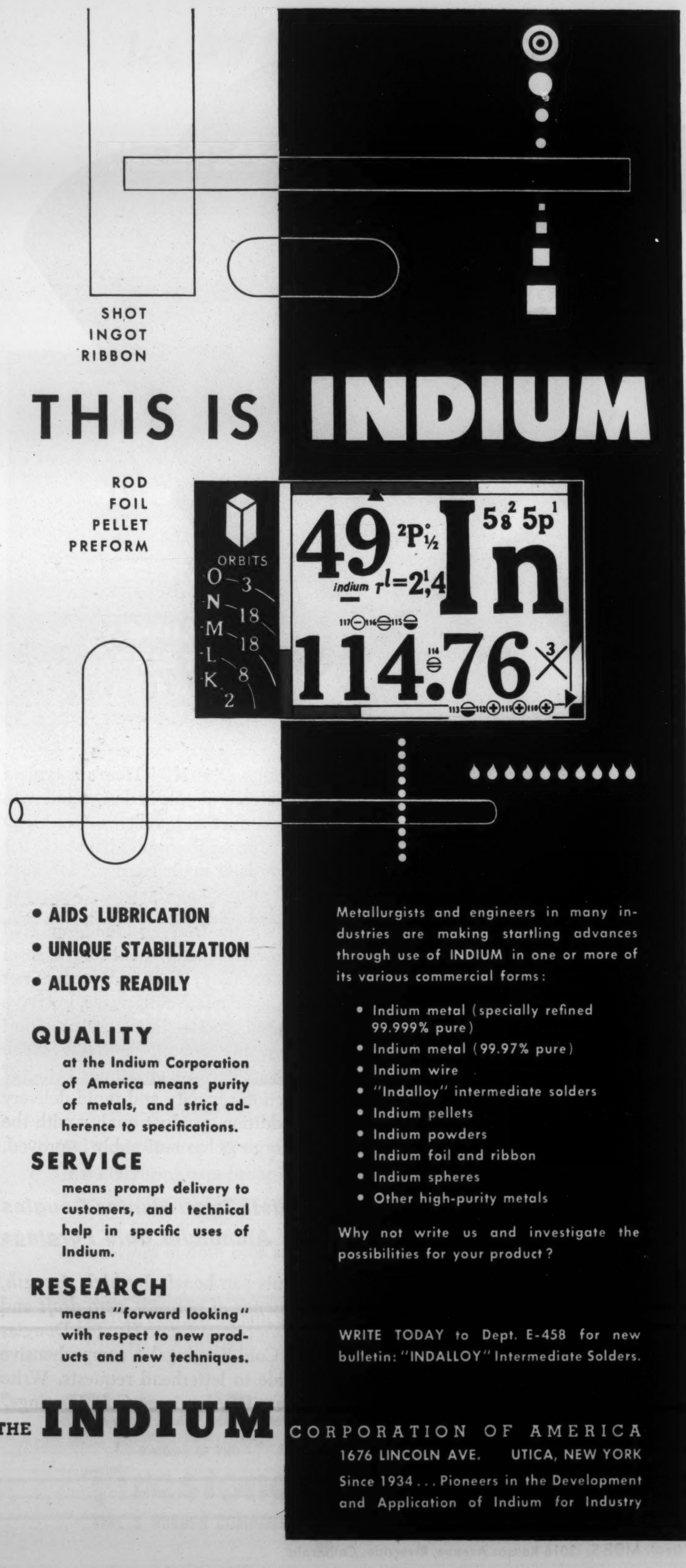

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PROPERTIES OF V-204 LAMINATE[a]

ORIGINAL PHYSICAL PROPERTIES	
Tensile Strength, psi	53,000
Compressive Strength (edgewise), psi	50,000
Flexural Strength (flatwise), psi	80,000
Modulus of Elasticity, psi	4.2 x 10^6
Specific Gravity	1.96
AFTER HEAT AGING AT 500 F	
Tensile Strength (100 hr), psi	46,000
Compressive Strength (edgewise, 100 hr), psi	37,000
Flexural Strength (flatwise), psi	
½ Hr	55,000
100 Hr	59,000
Modulus of Elasticity, psi	
½ Hr	3.3 x 10^6
100 Hr	3.2 x 10^6

[a] Resin content: 23%.

on reinforced phenolics see MATERIALS & METHODS, Nov '53, p 87 and Feb '56, p 103.)

Barrett's resin

Plaskon Laminating Varnish V-204 is the name given to Barrett's new phenolic resin. It was developed specifically for the fabrication of lightweight aircraft parts which exhibit high strength at 500 to 600 F. Barrett says the resin has better heat resistance than any heat resistant phenolic previously available.

Uses—Plaskon V-204 has been field tested and is currently used in aircraft and missile parts in the form of asbestos and glass-reinforced laminates, glass honeycomb structures, and matched metal die and vacuum bag shapes.

Fabrication—The company says that vacuum bag molding at 12 to 14 psi, laminating at pressures from 100 psi to as high as 2000 psi, and matched metal die molding at even higher pressures are all feasible with Plaskon V-204-impregnated materials. Modification of the conventional vacuum bag molding process is necessary to permit the removal of volatiles and the water of condensation generated by the cure of the phenolic resin. A number of presently used aircraft parts are fabricated by this method, including radomes, missile heads and com-

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THAT SOME FUNCTIONAL METAL PART COULD BE MADE BETTER OR CHEAPER BY ALUMINUM EXTRUDING?

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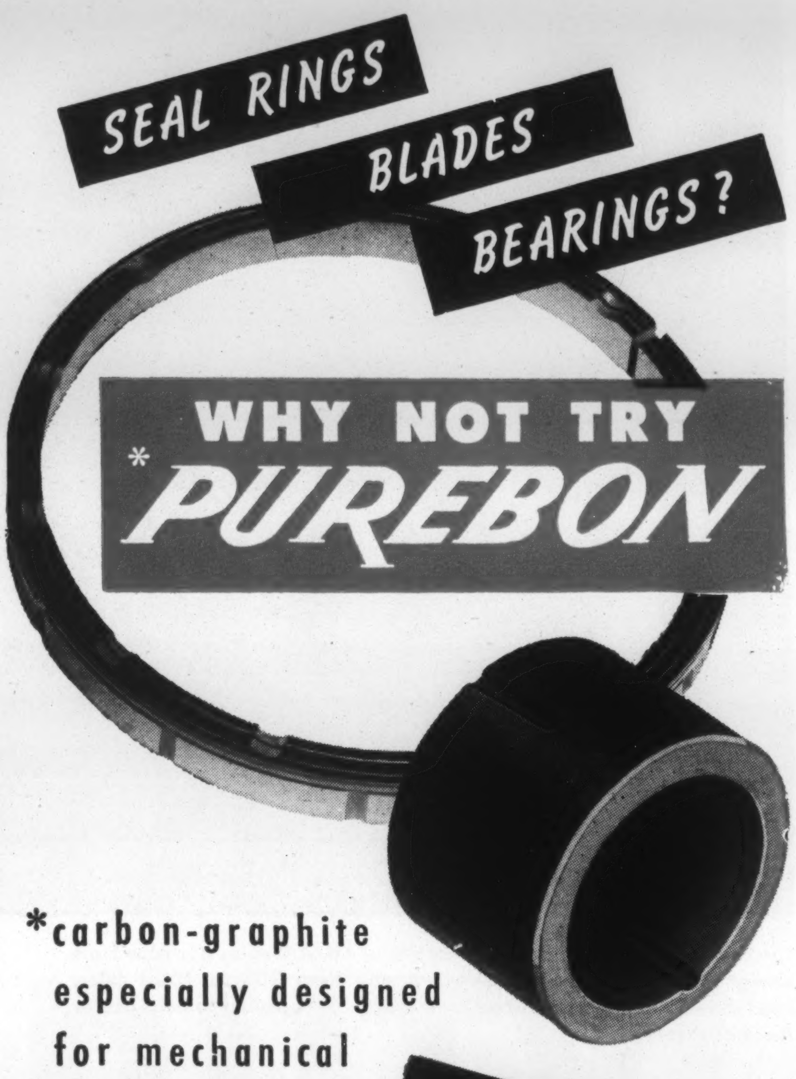
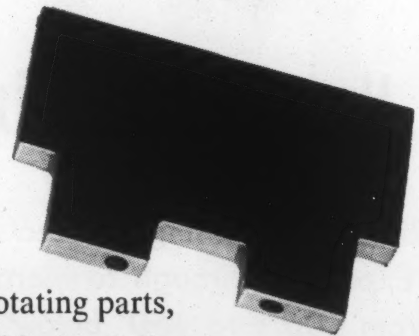


*carbon-graphite especially designed for mechanical applications



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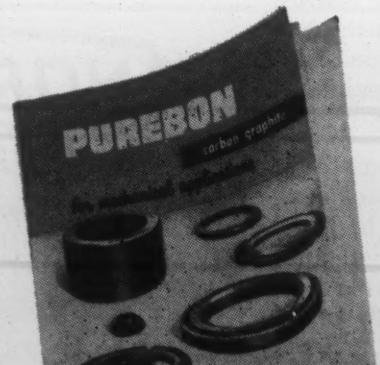

PURE CARBON CO., INC.
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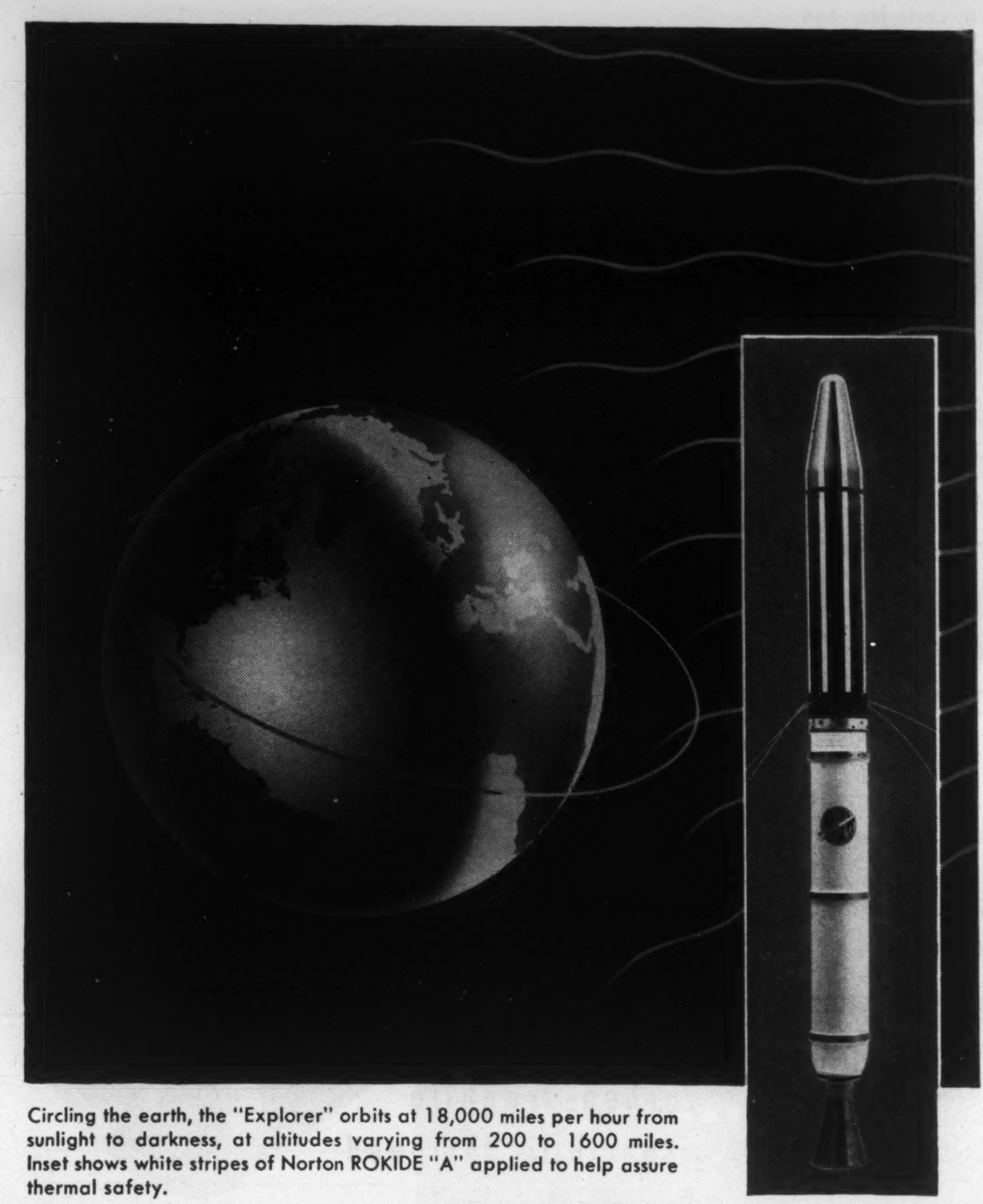

Circling the earth, the "Explorer" orbits at 18,000 miles per hour from sunlight to darkness, at altitudes varying from 200 to 1600 miles. Inset shows white stripes of Norton ROKIDE "A" applied to help assure thermal safety.

Hotter than fire . . . colder than ice

ROKIDE coating protects the "Explorer" through temperatures from 600°F to 150° below zero.*

Completing its orbit every 118 minutes, the "Explorer" speeds between blazing daylight and black night every hour, through temperatures ranging from 600°F to 150°F below zero.

The resultant thermal risks, especially to instruments, are enormous. By striping the satellite's nose cone and instrument section with ROKIDE "A" aluminum oxide spray coating, Jet Propulsion Laboratory scientists were able to maintain a safe internal temperature range.

ROKIDE "A", "ZS" and "Z" coatings are hard, crystalline refractory oxides. These Norton developments have high resistance to excessive heat, abrasion and corrosion that has proved valuable not only in reaction motors and AEC projects, but to general industry.......... in applications involving electrical insulation, electronics, bearing surfaces, erosion resistance, chemical barriers, material upgrading, surface catalyst activity and altering emissivity and characteristics of surfaces.

Facilities for applying ROKIDE coatings are maintained at Norton Company, Worcester, Mass., and at its plant at 2555 Lafayette Street, Santa Clara, Cal. For the latest ROKIDE Bulletin write to NORTON COMPANY, 704 New Bond Street, Worcester 6, Massachusetts.

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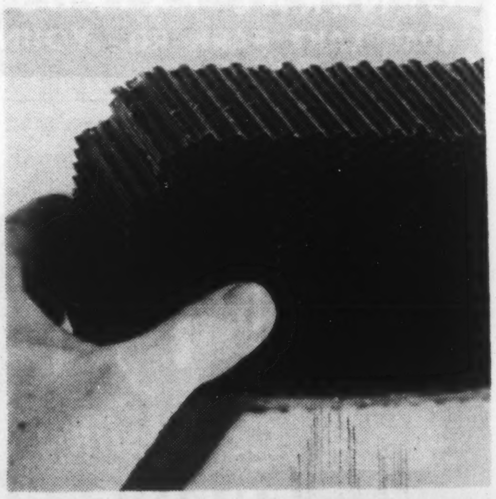
plex-shaped structural aircraft parts.

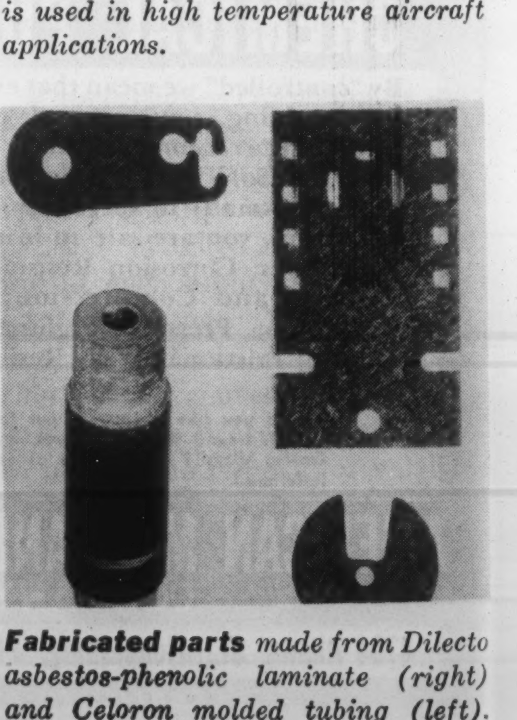
Laminates, parts

Continental-Diamond Fibre Corp.'s phenolic laminate is made from extra long staple nonferrous asbestos fibers that have been impregnated with a heat resistant phenolic resin. In addition to the laminate, the company is making available molded tubes, rods and parts made of the same heat resistant phenolic combined with suitable types of asbestos fibers.

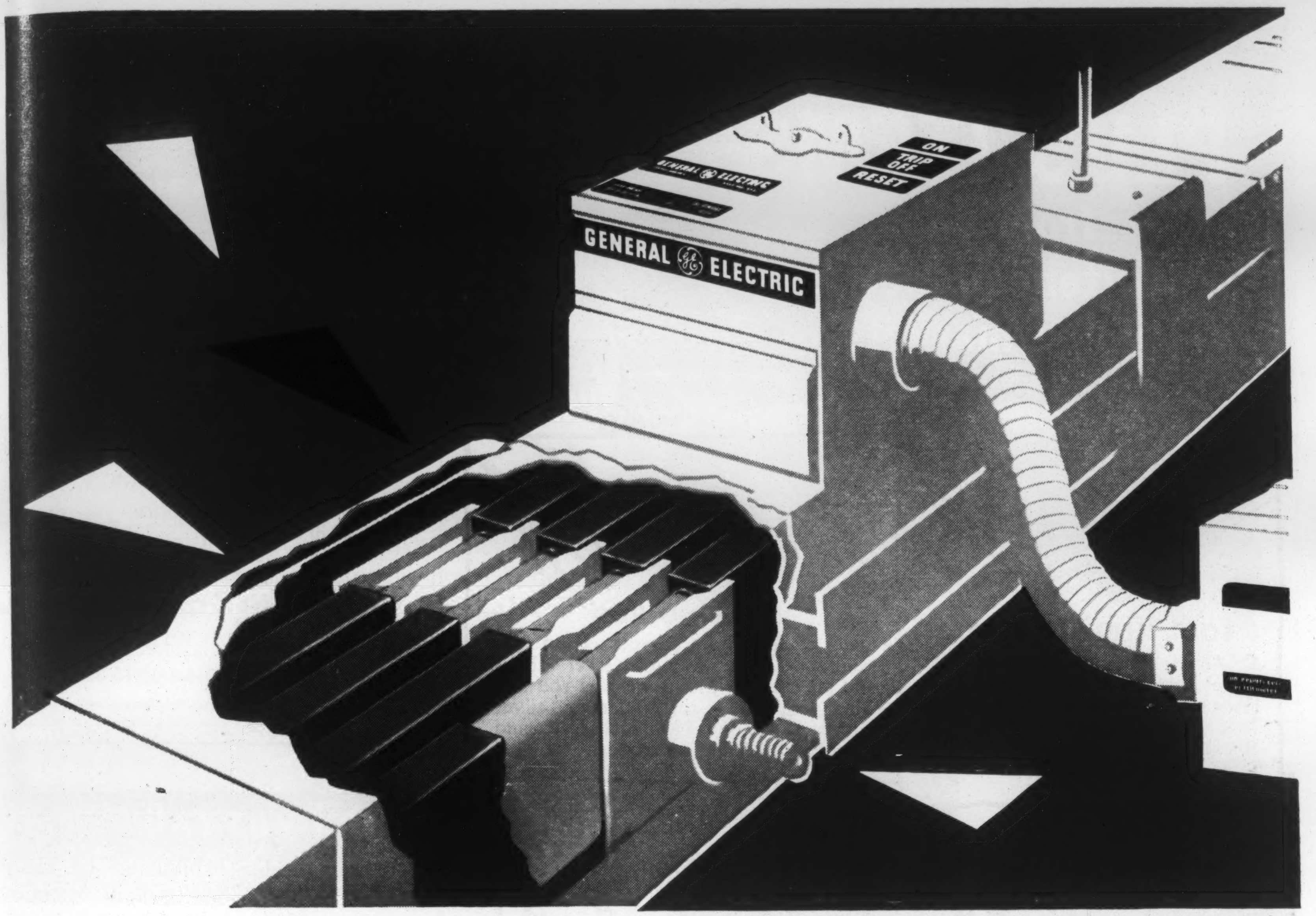
The laminates, called Dilecto, and the molded parts, called Celoron, are said to withstand 6 to 10-sec exposures to 3500 F, 60-sec exposures to 2500 F, intermittent exposures to 900 F, and continu-



Honeycomb structure *impregnated with Barrett's V-204 phenolic resin is used in high temperature aircraft applications.*



Fabricated parts *made from Dilecto asbestos-phenolic laminate (right) and Celoron molded tubing (left).*



When Enjay Butyl is used as continuous insulation of tubular aluminum conductors, traveling arcs are virtually eliminated, plug outlets are essentially dead-front.

ENJAY BUTYL

helps keep costs low in new Aluminum Busway!

Enjay Butyl is extruded over the full length of the conductors used in General Electric's new Type DE Busway, the first busway designed specifically for aluminum. This new busway incorporates all 22 features that engineers consider important in busway design, yet it is up to 30% smaller and 50% lighter than other busways of comparable rating.

Enjay Butyl rubber is ideal for use as continuous insulation of tubular conductors because of its inherent resistance to ozone and to heat aging. Add Butyl's excellent electrical properties, its vulcanizability and the fact that it is the *lowest cost* rubber on the market—and you'll understand why it was chosen above all other rubbers to do this job.

Every day manufacturers are discovering new ways to use economical Butyl. Find out how Enjay Butyl rubber can cut production costs for you. For further information and expert technical assistance, contact the Enjay Company.

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Enjay Butyl is the greatest rubber value in the world. It's the super-durable rubber with *outstanding* resistance to aging • abrasion • tear • chipping • cracking • ozone and corona • chemicals • gases • heat • cold • sunlight • moisture.

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These "Plus Items" and many more are available in addition to a wide selection of corrosion-resistant sheet, rod and tube.

All told, there are more than 20,000 items distributed and serviced by Whitehead. All are available, off-the-shelf, from the nine Whitehead Metal "Supermarkets." All are the products of such leading producers as Alcoa, Anaconda, Inco & Crucible Steel to name just a few.

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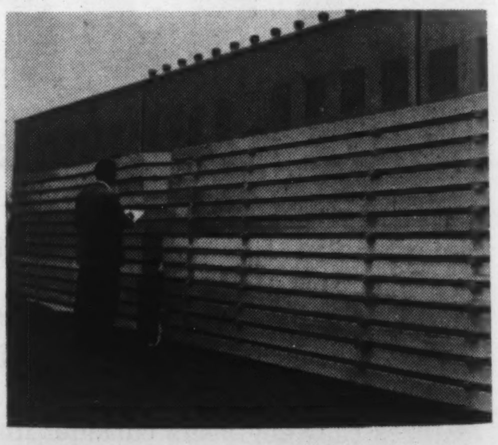
PROPERTIES OF DILECTO LAMINATES

ORIGINAL PHYSICAL PROPERTIES	
Tensile Strength, psi	50,000
Flexural Modulus, psi	5.5×10^6
Flexural Strength, psi	55,000
RETENTION OF PROPERTIES AFTER HEAT AGING	
Flexural Strength, %	
200 Hr at 300 F	87
100 Hr at 500 F	73
200 Hr at 500 F	60
5 Hr at 700 F	47
½ Hr at 1000 F	22
Flexural Modulus, %	
200 Hr at 300 F	87
100 Hr at 500 F	85
200 Hr at 500 F	71
5 Hr at 700 F	50
½ Hr at 1000 F	36

ous exposure to 500 F.

Uses—Specific applications in use or under evaluation by aircraft and guided missile manufacturers are: missile fins and exhaust columns, rotor and compressor blades in jet engines, missile nose sections, heat and flame barriers, insulators on rocket nozzles, liners in rocket engines, honeycomb structures, hot



Aluminum bus conductors—Harvey Aluminum Co. says the bus conductors shown above are the largest ever extruded. They measure 4⅛ x 20 in. in lengths up to 43 ft. The company says the surface finish of the extruded product is better than that of conventional rolled bus conductors, and conductivity is improved because the grain flow is in one direction. When installed, the bus conductors will carry 90,000 to 100,000 amp.

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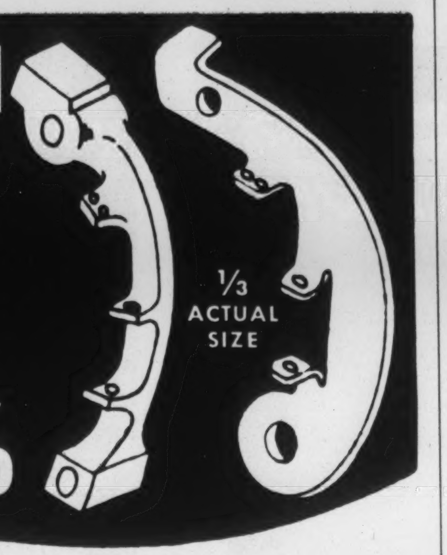
FROM CASTING
TO STAMPING
CUTS
CUSTOMER'S
COST 54%



Formerly a casting was used involving machining and drilling at $1.76 each. Converted to a stamping, the part was blanked, punched and formed at only $81.00 for the first 100 pieces. Subsequent 100 lots cost only 13¢ each—a 93% saving for the customer.

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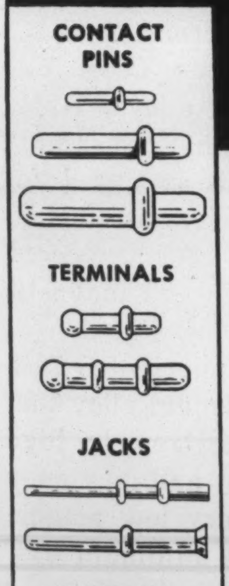

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Send sketch for quotations.

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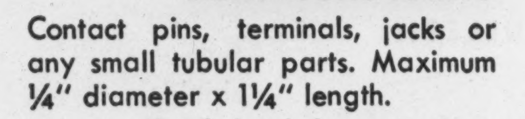
Low-speed positive drives or motion transfer ... at far less cost!



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THE BEAD CHAIN MFG. CO.

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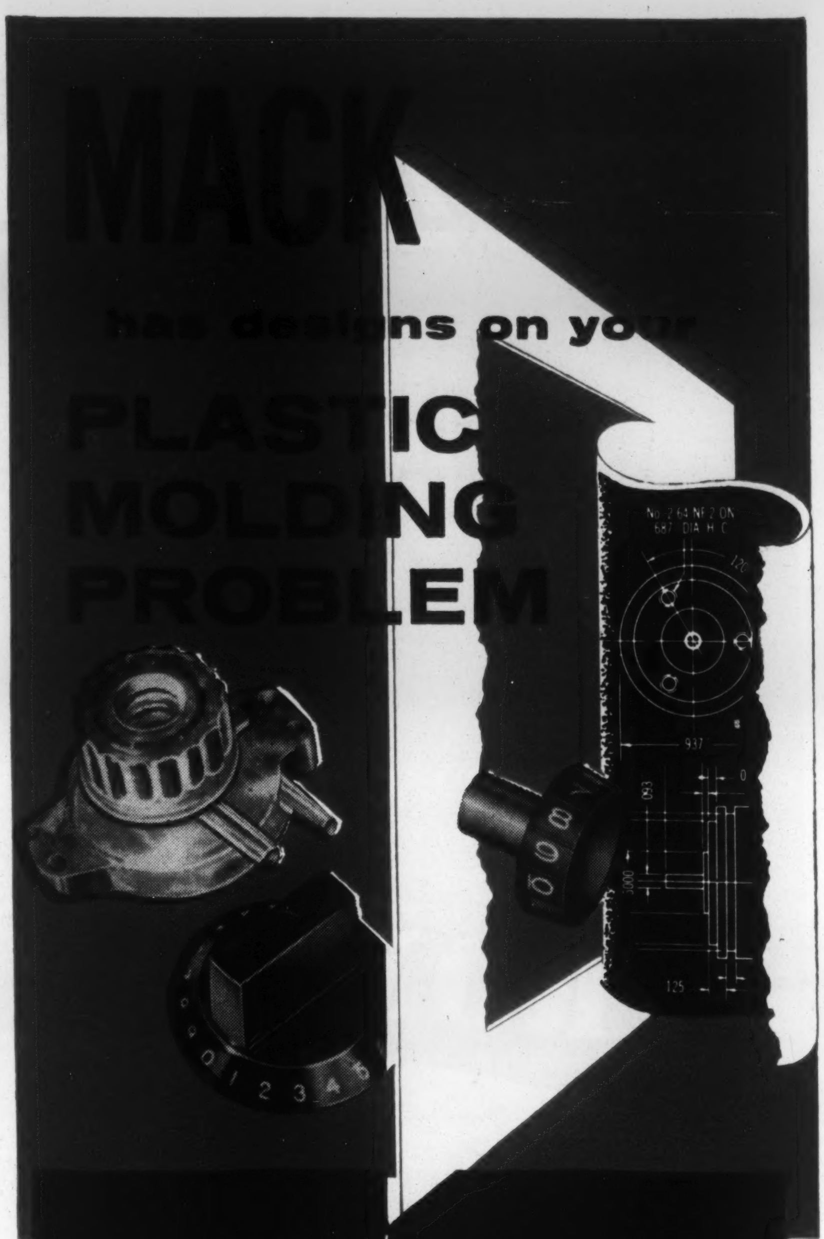

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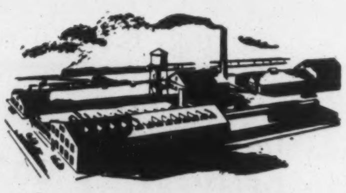

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air baffles, and molded structures exposed to the direct blast from burning rocket propellants.

Properties — The asbestos-phenolic laminates and parts (high pressure types) are said to have good mechanical strength at low and high temperatures, low porosity, good dimensional stability, good chemical and water resistance, a smooth and nonabrasive surface, high impact strength, and good insulating and thermal properties.

Fabrication—Dilecto laminates and Celoron molded parts can be fabricated and machined by conventional methods, including drilling, milling, tapping, sawing, countersinking, counterboring and threading. Laminates up to 1/16 in. thick can be cold punched by conventional techniques.

Nickel-Iron Alloys for Electronic Devices

Four high permeability alloys are now available as thin strips in thicknesses from 0.002 to 0.006 in. and in widths from ¼ to 3¼ in. from Carpenter Steel Co., Reading, Pa. The alloys, HyMu 80, Hy-Ra 80, High Permeability 49 and Hy-Ra 49, are used for such electronic devices as magnetic amplifiers, transformer cores, tape wound toroids and magnetic shields.

HyMu 80 is an unoriented 79% nickel-iron-molybdenum alloy that is said to offer extremely high initial permeability and maximum permeability at very low magnetizing forces with minimum hysteresis loss.

Hy-Ra 80 is a 79% nickel-iron-molybdenum alloy specifically processed to exhibit a square hysteresis loop. It is said to have high initial permeability and maximum permeability with low hysteresis loss.

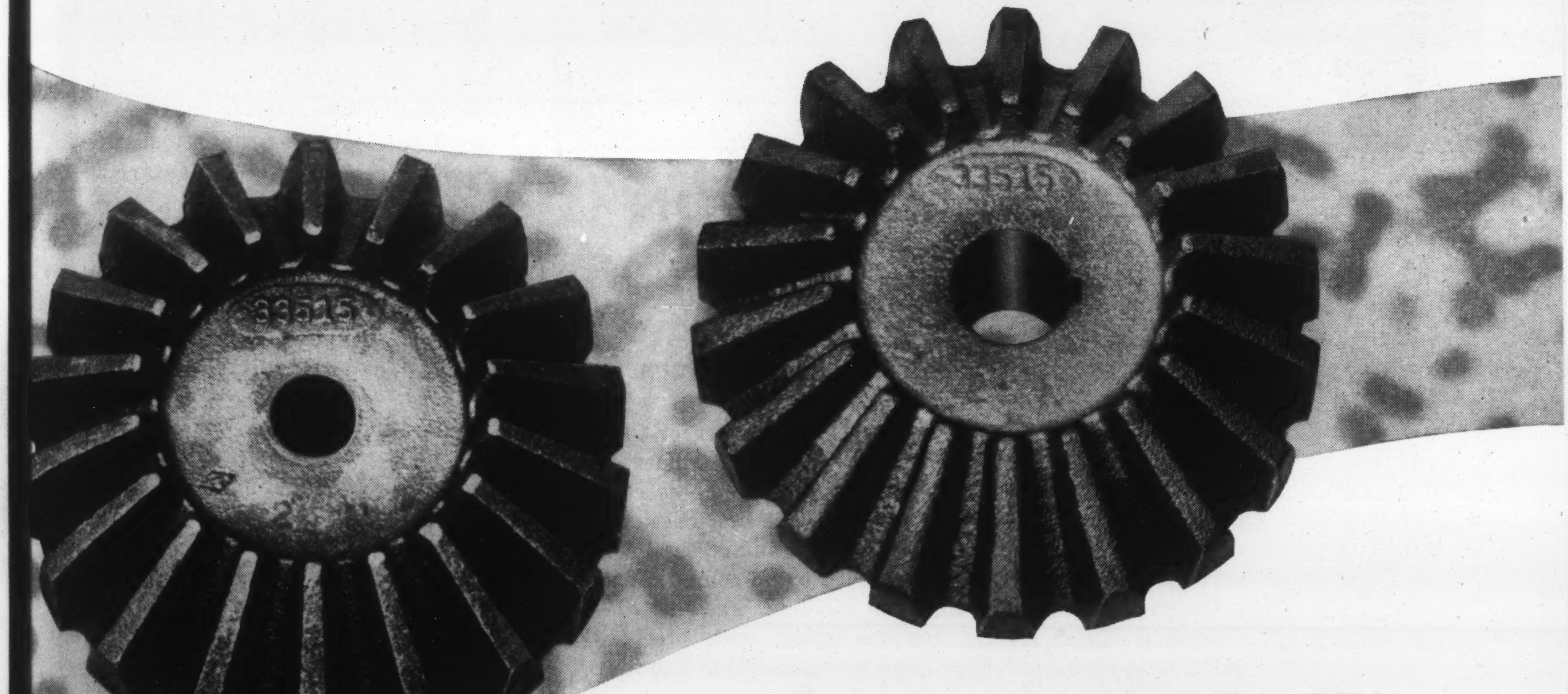
High Permeability 49 is an unoriented 49% nickel-iron alloy

For more information, circle No. 415 ➤

is your problem **wear resistance?**

NATIONAL HTM CASTINGS

are the answer



There are many reasons for specifying HTM (Pearlitic Malleable) castings. One is *extreme wear resistance under heavy loads at high speeds.*

But there are many other reasons, too. For example, close as-cast tolerances can often eliminate machining operations such as on the gear teeth shown above. In this case, it was only necessary to drill and machine the key slot.

Other worthwhile advantages of HTM are high ultimate strength . . . excellent non-seizing bearing qualities that can eliminate costly bushings . . . air or liquid quenching . . . ability to be smooth-finished.

So when you're looking over the materials field, don't overlook the advantages of HTM castings. For HTM metal can be cast by either the shell mold, CO_2, or green sand method. This means production costs tumble . . . performance and saleability of your product go up.

AA-6928

IMPORTANT PHYSICAL PROPERTIES	
Brinell	163 to 302*
Yield, psi	48,000 to 85,000*
Ultimate, psi	70,000 to 110,000
Elongation, %	7 to 2*

NATIONAL MALLEABLE and STEEL **CASTINGS COMPANY**

Established 1868 *Cleveland 6, Ohio*

The nation's largest independent producer of malleable and pearlitic malleable which has a saturation flux density of approximately 16,000 gauss after hydrogen annealing.

Hy-Ra 49 is an oriented 49% nickel-iron alloy specially processed to exhibit a square hysteresis loop. After hydrogen annealing, a square hysteresis loop is produced when the magnetic field is parallel to the cold rolling direction.

Fluorocarbon Laminate

International Resistance Co., 401 N. Broad St., Philadelphia 8, has introduced Fluoroply-F, a fluorocarbon-base plastics laminate, for printed circuit applications. The laminate is said to have good dielectric properties, good high frequency characteristics and an arc resistance of more than 360 sec. The fluorocarbon plastics laminate can be readily cold punched, drilled and machined.

How Solvents, Acids Affect Viton Rubber

Additional information on the chemical resistance of a relatively new fluoro-elastomer, Viton, has been released by E. I. du Pont de Nemours & Co., Inc., Wilmington, Del. These data are shown in an accompanying table. Other data, taken from tests conducted by the company and by Wright Air Development Center, show that it takes 24 hr instead of 8 hr to produce brittleness in a Viton sample exposed to a temperature of 600 F. Brittleness data at other temperatures, namely 400, 450, 500 and 550 F, are essentially the same as reported in the July '57 issue of MATERIALS IN DESIGN ENGINEERING (p 96).

Viton, a copolymer of vinylidene fluoride and perfluoropropylene, has outstanding resistance to heat (temperatures over 400 F), aro-

CHEMISEAL® NYLON

performer

Design to use Chemiseal Nylon (du Pont ZYTEL) for those mechanical and electromechanical parts that must be strong, durable, wear resistant. It has the highest compressive strength, is the most rigid, has the best resistance to heat, abrasion, chemicals, solvents, oils and greases. And it is the lowest priced of the standard nylon compositions.

Coupled with U.S.G.'s Injection Molding "know-how"—Chemiseal Nylon assures you the lowest cost, precision parts, in volume production. And we specialize in handling designs difficult to mold.

U.S.G. Nylon service goes all the way—offering not only injection molding of parts but also a complete stock of bubble-free Nylon rod, standard and pressure tubing, tape and extruded shapes. In addition, extensive, specialized facilities for high speed automatic machining of parts from stock to your specifications.

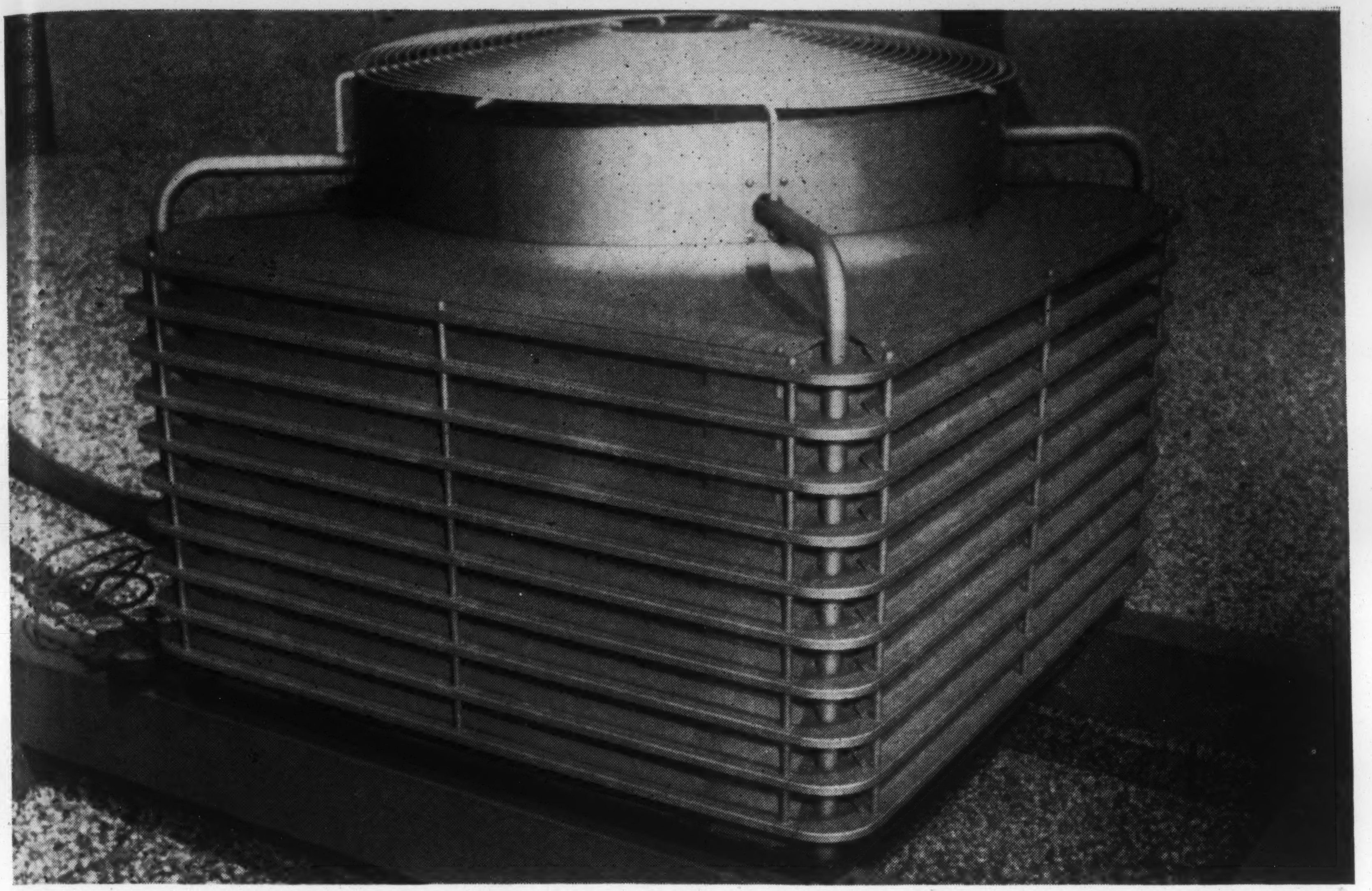
For prompt service, contact one of The Garlock Packing Company's 30 sales offices and warehouses throughout the U.S. and Canada, or write

United States Gasket Company
Camden 1, New Jersey

United
States
Gasket

Plastics Division of
GARLOCK

For more information, turn to Reader Service card, circle No. 535



How Armco ALUMINIZED STEEL Type 2 Cut Costs and Improved Durability of Air Conditioner Housing

Special hot-dip aluminum-coated steel provides low-cost resistance to atmospheric corrosion, eliminates need for paint

A leading manufacturer of air conditioners formerly made the housings for the condenser units from cold-rolled steel. They had to be painted inside and out for surface protection and good appearance. Now, with all sheet metal parts made of Armco ALUMINIZED STEEL Type 2, *only the outside* is painted—and that because of a color identification of long standing.

Production Costs Down

Elimination of paint on the inside of the housing has reduced paint and labor costs 50%. And shop men report that with moderate care, parts can be fabricated of ALUMINIZED STEEL just as easily as with uncoated steel.

Better Durability

Originally the decision to use ALUMINIZED STEEL was based on tests which showed no rusting after 15 years' continuous exposure in an industrial atmosphere. Now service records prove that even under severe conditions the ALUMINIZED STEEL housings have lasting resistance to rust and corrosion, provide much longer service life.

Save on *your* production costs and give your outdoor products customer-attracting durability with the multiple advantages of Armco ALUMINIZED STEEL Type 2. Just fill out and mail the coupon for complete information.

ARMCO STEEL CORPORATION
1628 Curtis Street, Middletown, Ohio

Send me design and fabrication information on Armco ALUMINIZED STEEL Type 2.

We are considering it for____________________

NAME____________________

COMPANY____________________

STREET____________________

CITY__________ZONE_____STATE__________

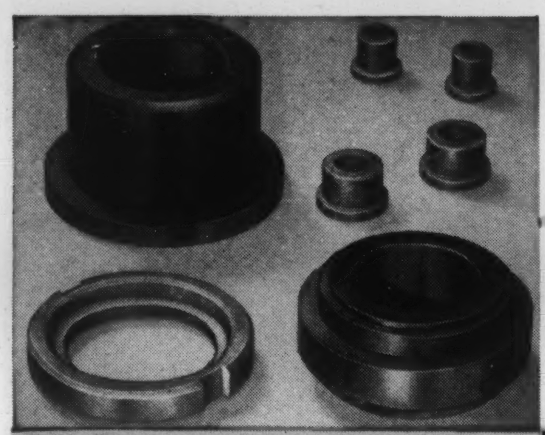
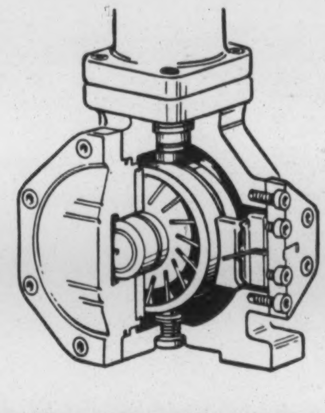
ARMCO STEEL

ARMCO ®

ARMCO STEEL CORPORATION • 1628 CURTIS STREET, MIDDLETOWN, OHIO

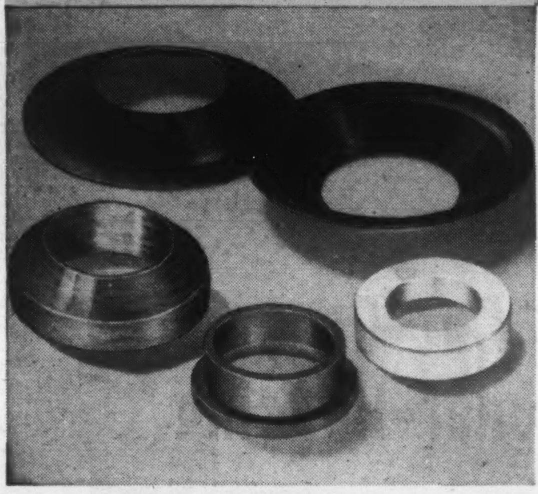
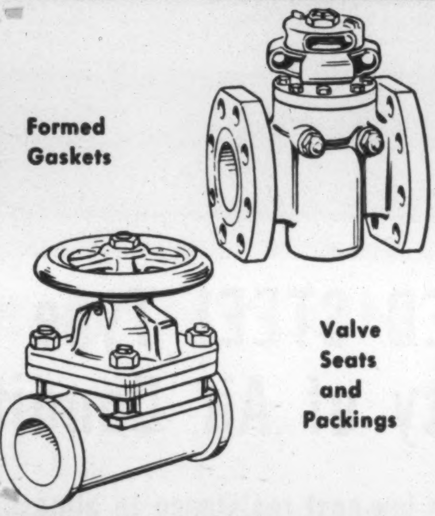
SHEFFIELD DIVISION • ARMCO DRAINAGE & METAL PRODUCTS, INC. • THE ARMCO INTERNATIONAL CORPORATION

For more information, turn to Reader Service card, circle No. 424

HAVE YOU CONSIDERED THE IMPORTANT ADVANTAGES OF FILLED TEFLON*?

Electronic Bushings,
Insulators
and
Tuning
Slugs
Rod & Tubing

It has been definitely established that the value of Teflon can be considerably enhanced by the use of fillers in certain applications. Laboratory and field experience has demonstrated that the use of fillers permit Teflon to be more readily tailored to a wide variety of chemical, electrical and mechanical applications. Also, some mechanical properties can be improved. These include:

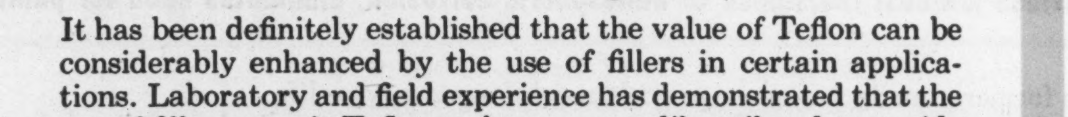
1) resistance to deformation under load
2) resistance to wear
3) thermal conductivity
4) compressive strength
5) hardness

By thus improving its properties, Teflon now offers even greater industrial potential. This is the reason filled Teflon has become an important item in the "John Crane" Chemlon® line of better Teflon products.

Chemlon is available with such fillers as glass fiber, carbon, graphite, copper and bronze, talc, calcium fluoride and other inorganic materials.

Crane Packing Company, 6460 Oakton Street, Morton Grove, Illinois, (Chicago Suburb). In Canada: Crane Packing Co., Ltd., Hamilton, Ont

***DuPont Trademark*



CRANE PACKING COMPANY

For more information, turn to Reader Service card, circle No. 392

EFFECTS OF FLUIDS ON VITON[a]

	Ten Str Chg, %	Elong Chg, %	Vol Chg, %
SOLVENTS			
Carbon Tetrachloride, 75 F	−15	−17	+1.3
Ethyl Alcohol, 75 F	− 3	0	+1.7
Aniline, 75 F	0	0	+ 3
Tricresyl Phosphate, 300 F	− 7	0	+ 24
Acetone, 75 F	—	—	+271
Methyl Ethyl Ketone, 75 F	—	—	+287
FUELS AND LUBRICANTS			
JP-5, 75 F	0	0	+ 0.4
JP-4, 75 F	− 3	0	+ 0.8
70/30 Isooctane/ Toluene, 75 F	− 7	0	+ 2.5
ASTM No. 3 Oil, 300 F	− 5	0	+ 4.3
Benzene, 75 F	−27	− 8	+19.6
Mil-L-7808, 400 F	−40	−13	+19.6
HYDRAULIC FLUIDS			
Transmission Fluid (Type A), 212 F	−23	−21	+ 1.5
Oronite 8200, 300 F	− 7	0	+ 1.8
OS-45, 400 F	−38	−33	+11.1
Skydrol 500, 300 F	—	—	+270
ACIDS AND BASES			
Sodium Hydroxide (46.5%), 75 F	−25	0	+ 2.1
Water, 212 F	− 2	0	+ 2.7
Sulfuric Acid (fuming), 75 F	−42	−31	+ 4.8
Hydrofluoric Acid (48%), 75 F	− 2	0	+ 4.8
Hydrochloric Acid (36.5%), 75 F	−19	−19	+ 7.3
Nitric Acid (red fuming), 75 F	—	—	+ 16
Acetic Acid (glacial), 75 F	—	—	+61.6

[a] **Seven days immersion.**

matic and aliphatic hydrocarbons, dilute and concentrated mineral acids and alkalis, petroleum hydrocarbons and water.

For information on some current uses of the material, see p 12.

Lead-Arsenic Alloy Increases Battery Life

A relatively new lead battery alloy called Silvium shows promise of increasing the life of automo-

How Glidden can help you produce better Metal Powder Parts...

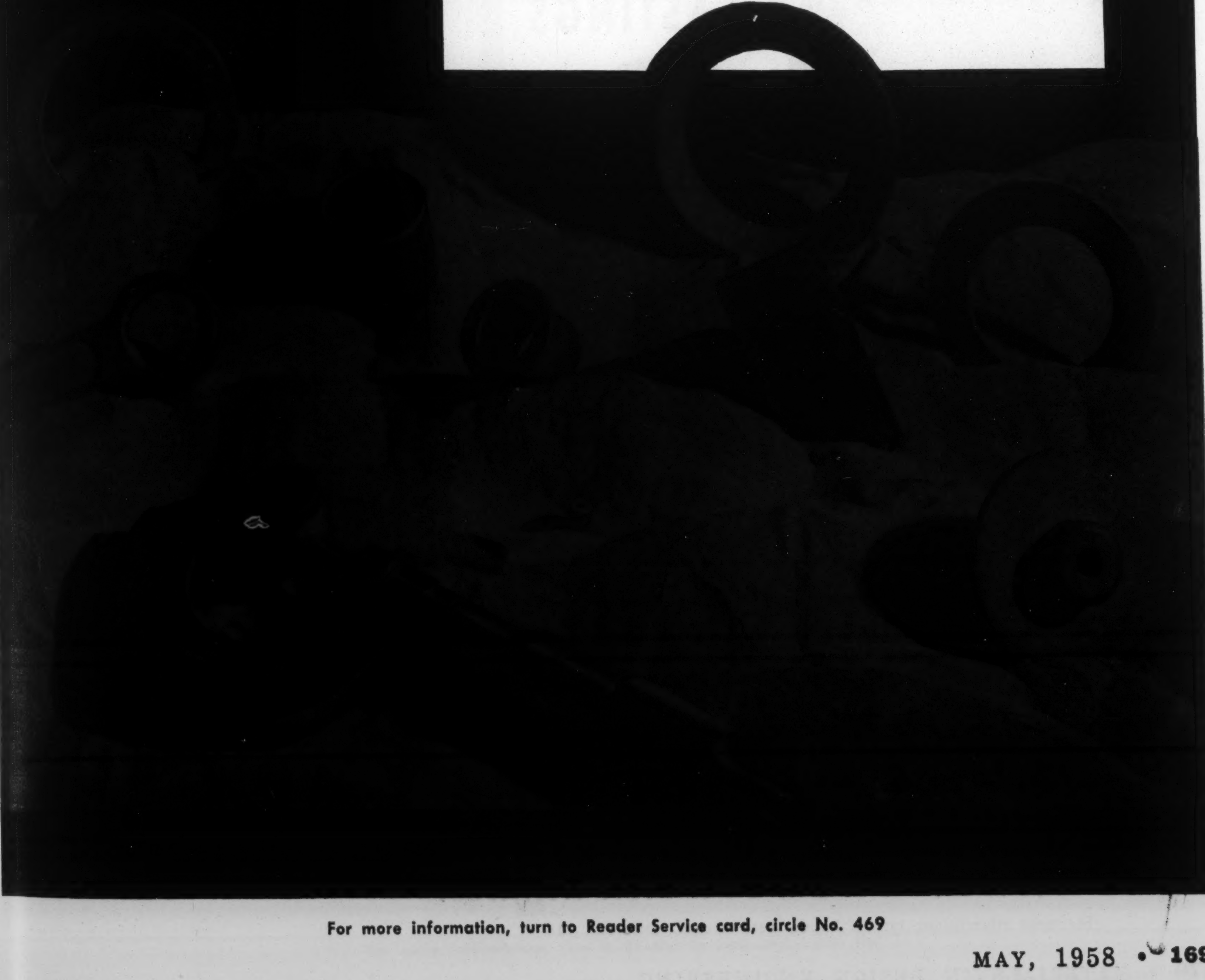
Whether you are interested in improving the operation of an existing metal powder parts department, or desire to establish a new parts department, Glidden can help you.

Glidden not only offers the helpful assistance of its metal powders lab and trained metallurgists, but can also supply you with RESISTOX Metal Powders that permit faster production of precision parts with greatly improved finish, appearance and performance characteristics. And Glidden has the facilities to produce up to 30,000 pounds of RESISTOX Metal Powders in one batch—an important factor in complete uniformity of mass-produced parts.

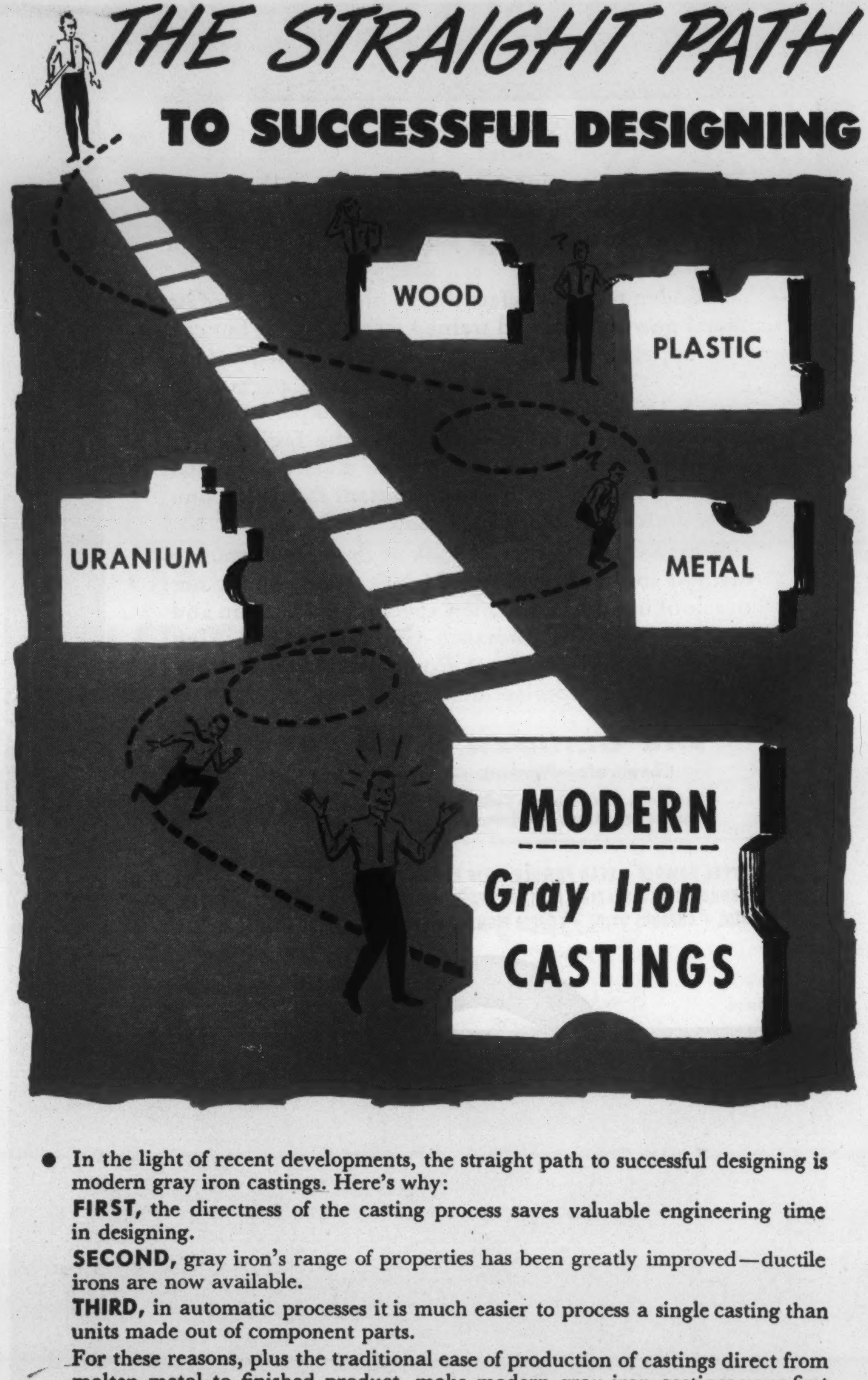
Why not take a careful look at the manufacturing method you are now using. Make certain you are not overlooking the economies, speedier fabrication and superior parts performance you can get by using Glidden RESISTOX Metal Powders. Write on your letterhead for complete details.

THE GLIDDEN COMPANY
Chemicals—Pigments—Metals Division
Baltimore, Maryland • Collinsville, Illinois
Hammond, Indiana • Scranton, Pennsylvania

COPPER POWDER • LEAD POWDER • TIN POWDER
CUBOND COPPER BRAZING PASTE • BRASS POWDER • ALLOY POWDER • CUPRIC OXIDE • CUPROUS OXIDE • COPPER PIGMENT • CUPROUS SULPHIDE • FILTER POWDER



For more information, turn to Reader Service card, circle No. 469



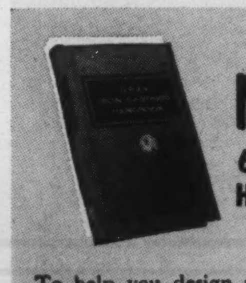
- In the light of recent developments, the straight path to successful designing is modern gray iron castings. Here's why:

FIRST, the directness of the casting process saves valuable engineering time in designing.

SECOND, gray iron's range of properties has been greatly improved—ductile irons are now available.

THIRD, in automatic processes it is much easier to process a single casting than units made out of component parts.

For these reasons, plus the traditional ease of production of castings direct from molten metal to finished product, make modern gray iron castings your first consideration.



NEW
620 Page Handbook

To help you design successfully and economically, the Gray Iron Founders' Society has compiled this 620-page handbook. Just off the press, this valuable reference has hundreds of suggestions on how to improve products and cut manufacturing costs. Covers 263 subjects on properly designing, purchasing and applying gray and ductile iron castings.

GRAY IRON FOUNDERS' SOCIETY INC.
National City-East Sixth Building
Cleveland 14, Ohio

Please send your 620-page handbook for TEN DAYS FREE EXAMINATION. At the end of the examination period I will remit $10 or return book.

☐ $10 enclosed ☐ Bill after 10 days
☐ Purchase Order enclosed

Name______________________________

Company______________________________

Address______________________________

City____________Zone_____State__________

TIME TO DESIGN WITH *MODERN GRAY IRON CASTINGS!*

For more information, turn to Reader Service card, circle No. 434

bile and stationary storage batteries by as much as 240% over conventional lead battery alloys, according to the producer. Other advantages of Silvium are: good electrical conductivity, high strength and good grain structure when cast into battery grids.

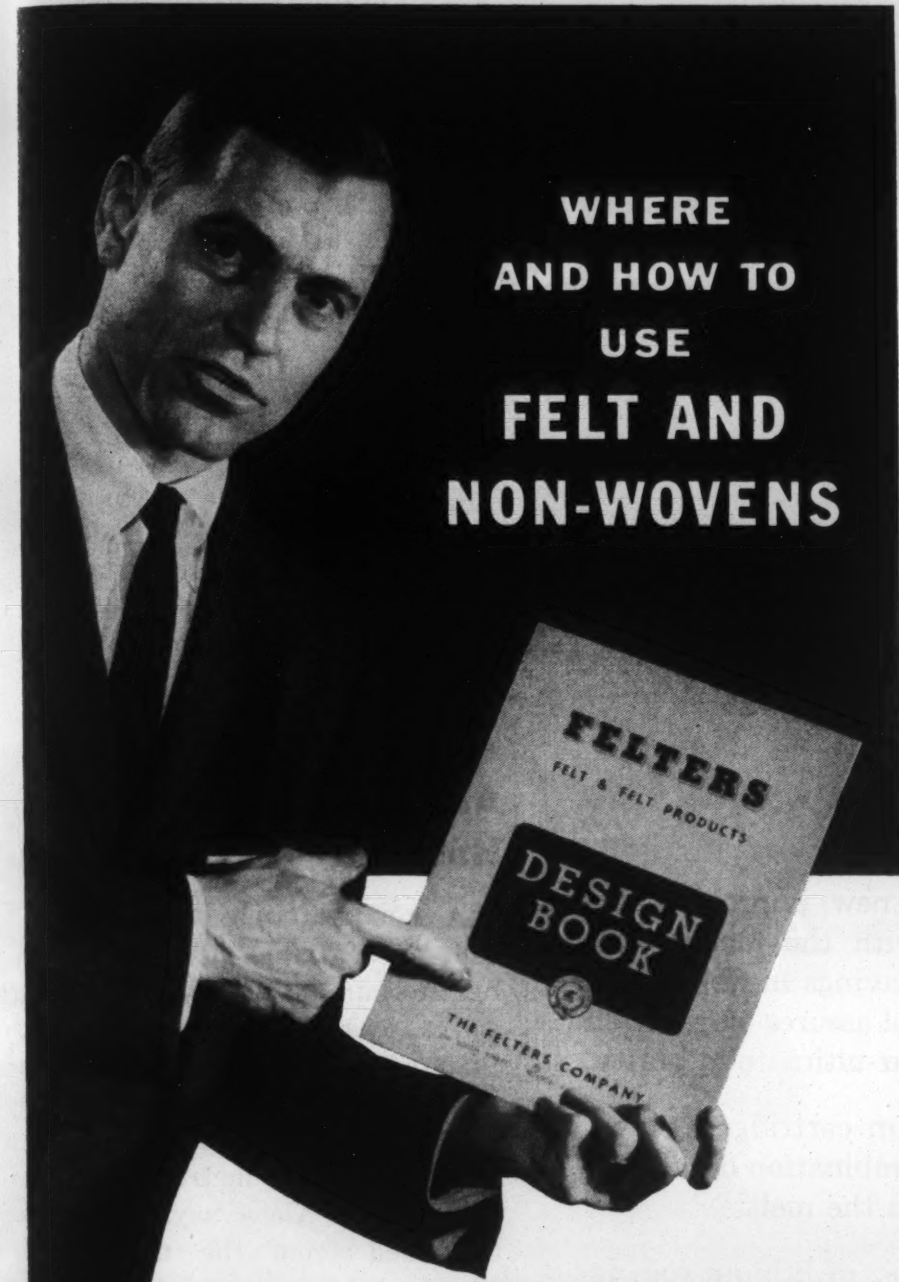
Developed by H. Stoertz of the Research Dept., Electric Storage Battery Co., Philadelphia, Pa., the alloy is said to make battery grids, straps and posts less susceptible to electrochemical attack. Electrochemical attack occurs when a storage battery is overcharged (i.e., during a period when a battery is left "on the line" somewhat longer than necessary to bring it to a fully charged condition). During this period, antimony, and possibly some nickel and copper, is removed from the positive grid and dissolved in the electrolyte to form salts which decompose at the negative plate. Battery grids made of Silvium are said to retard deposition of foreign materials on the negative plate.

The alloy, containing 4 to 8% antimony, 0.15 to 1% arsenic, 0.04 to 0.60% silver and the remainder lead, has been field tested as a grid in heavy duty taxicab batteries. Of 20 batteries tested, only seven failed. The remaining 13 batteries are still being tested and have been run an average of 70,000 miles.

Asbestos-Silicone Cools Hot Aircraft Ducts

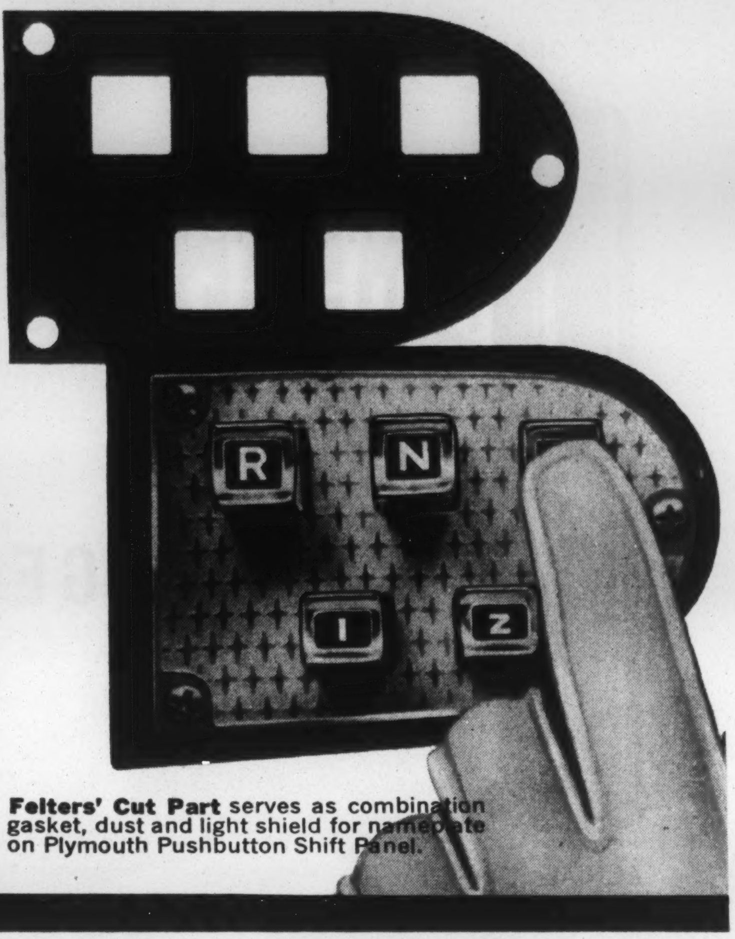
An asbestos-silicone combination has proved to be an effective thermal insulation for hot aircraft ductwork. The cured film, 0.13 in. thick, is said to reduce internal duct temperatures of 450 F to as low as 150 F on the exterior insulation surface. Comparable quartz blankets, 0.18 in. thick, are said to reduce the same internal

PHOTO REPORT:



WHERE AND HOW TO USE FELT AND NON-WOVENS

Free Design Book gives technical data on design properties, special treatments and selection. Send for your copy.



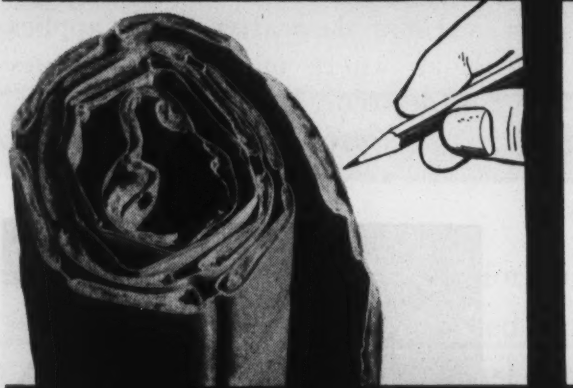
Felters' Cut Part serves as combination gasket, dust and light shield for nameplate on Plymouth Pushbutton Shift Panel.

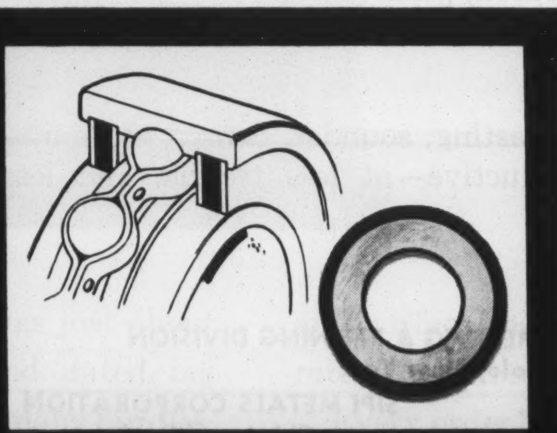
Felters' range of non-woven and felted-type fabrics offer wide combinations of characteristics not found in any other material.

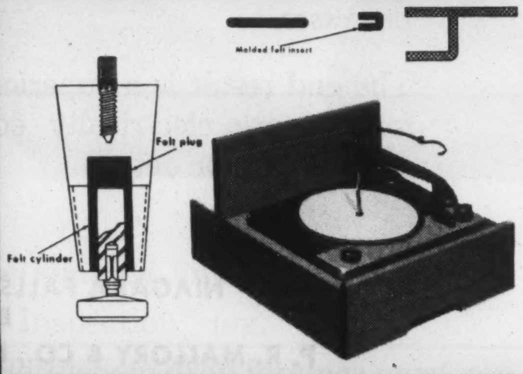
These fabrics can be made tough, stiff or dense, as required. Also water repellent, flameproof, and moth and mildewproof. Ideal for absorptive wicking and filtering applications.

Synthetics, too, are giving non-wovens new uses and properties, particularly in smoothness, abrasion resistance, and long life.

Call on Felters for all types of felt and non-woven fabrics, including special treatments, impregnations and fiber mixes.







AllFab is a special Felters' non-woven fabric. Has thermoplastic resin binder and can be electronically stitched, sealed and embossed. Available in wide range of fiber combinations in thicknesses from 1/16" to 1" and more. Used for backing, filling, and plumping. Available with synthetic mixes such as Orlon®, with varying degrees of "loft."

Felt Pads (Prelubricated) prolong bearing life! Special tests show that oil saturated felt rings provide a built-in "slow bleeding" action to lubricate bearings. Functions over wide temperature range at speeds up to 10,000 rpm, without excessive starting friction at low temperature or poor stability at high temperature.

Hi-Fi Sets Use Felt in a number of places. Record changer drawers slide on aluminum channel with molded in felt insert. This provides light compression fit, eliminates resonant metal-to-metal contact, absorbs vibration and insures smooth action. Special felt lined piston legs eliminate floor vibration which affects performance.

the **FELTERS** company

220 SOUTH ST., BOSTON 11, MASS.

Pioneer producers of Felt and Felt Products

For more information, turn to Reader Service card, circle No. 485

Introducing...

4.50 GRAMS

The New Look in

LITHIUM COPPER CARTRIDGES

ACTUAL SIZE

Lithium isn't new to foundrymen. But the new, improved, 4.50 gram cartridge is. Thinner walls react with the melt faster. Nearly 100% greater compactness means savings in weight and storage space. New "Compression-Spin" seal assures longer shelf life. Over 99.9% copper assay offers the near-ultimate in purity.

Three other handy sizes, 2.25 and 9.0 gram cartridges, plus a 108.0 gram charge in cup form, offer any combination of weights for introducing any percentage of lithium in the melt.

The 4.50 gram cartridge represents 0.010 lbs. of lithium rod. It will refine 200 lbs. of copper or copper-base alloy. All oxygen is removed, fluidity increased, pouring temperature often lowered, oxide and slag inclusions reduced, grain refined, and gas cavities eliminated—*with no change in conventional melting and casting processes.*

The end result is a superior casting: sounder, denser, more uniform, more electrically conductive—at less trouble and less cost. Write for details.

DISTRIBUTORS:

NIAGARA FALLS SMELTING & REFINING DIVISION
Buffalo, New York

P. R. MALLORY & CO., INC.
Indianapolis, Indiana

SIPI METALS CORPORATION
Chicago, Illinois

MITCHELL SMELTING & REFINING CO.
Botsford Center, Conn.

PACIFIC GRAPHITE CO., INC,
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LCA

LITHIUM CORPORATION OF AMERICA, INC.
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MINNEAPOLIS 1, MINN.

SALES OFFICES: NEW YORK — CLEVELAND — CHICAGO — MINNEAPOLIS

For more information, turn to Reader Service card, circle No. 482

What's new IN MATERIALS

duct temperature to only 200 F.

The insulation, developed by Cessna Aircraft Co., Wichita, Kan., and called Camco 400, is made of asbestos mixed with Dow Corning's C-271 silicone adhesive. Compounded in densities from 30 to 62 lb per cu ft, Camco 400 may be cured in service or by oven baking at 400 F for 1 hr. Cessna says the asbestos-silicone combination can easily be sprayed or brushed onto almost any plastics or metallic surface.

Aluminum Sheet Alloy Has Mirror-Like Finish

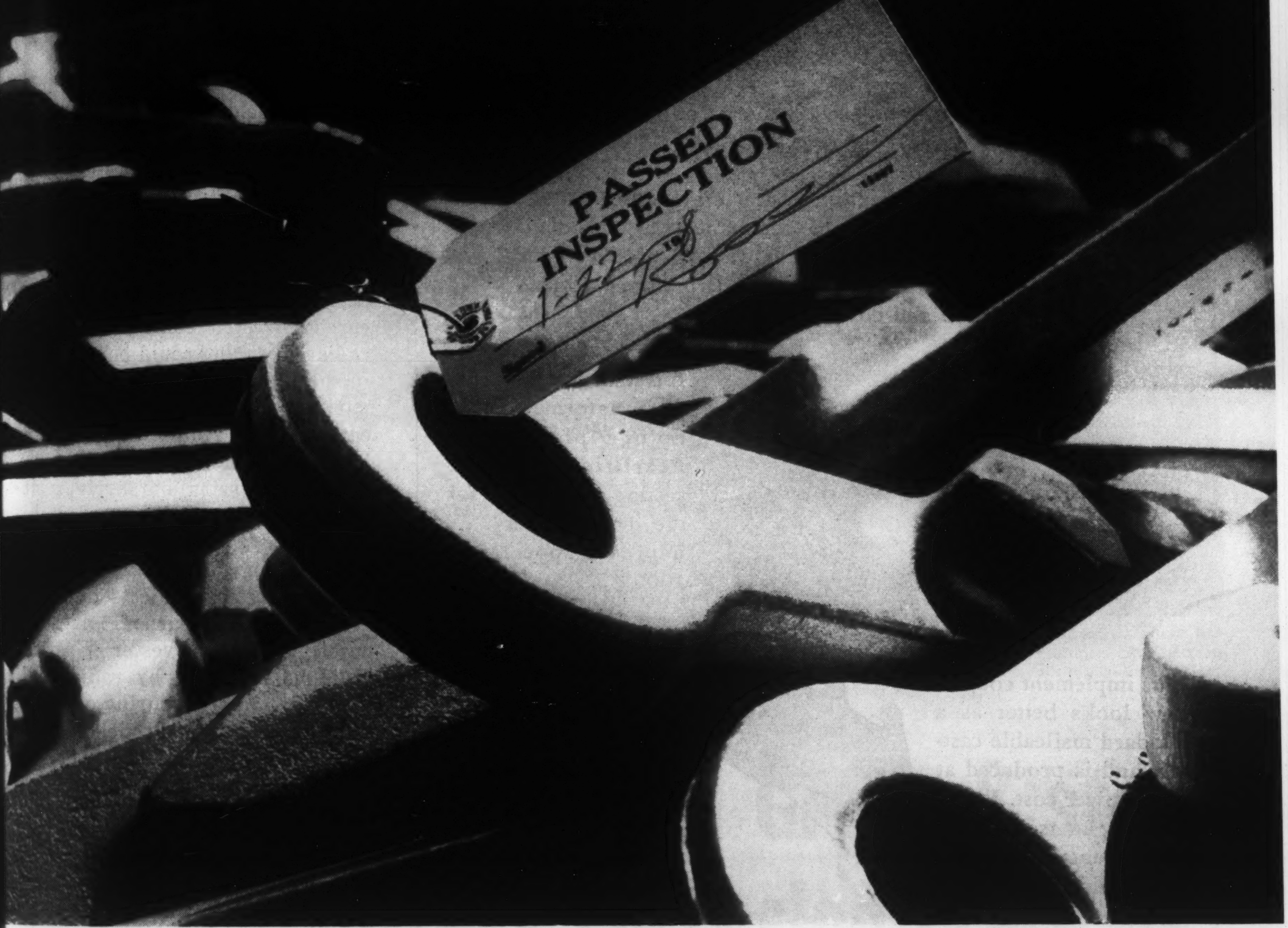
A new aluminum sheet alloy, called X5457, has been developed by Aluminum Co. of America, 1501 Alcoa Bldg., Pittsburgh 19, Pa. for use as decorative trim in automobiles and appliances. When polished, brightened and anodized, the sheet has a lustrous mirror-like finish. Alcoa says products fashioned from the new sheet alloy exhibit mechanical properties similar to those of 5357 alloy and can be rolled to the same specifications. The new alloy is expected to replace alloy 5357 in various decorative trim applications where optimum brightness is desired.

(more What's New on p 174)

Reflection *is caught on mirror-like surface of Alcoa's new aluminum sheet alloy.*

For more information, circle No. 474

They've Cleared the Last Hurdle



Here are some Bethlehem drop forgings just about ready for shipment. That signed and dated tag means that they have taken the last of many hurdles. They've survived every check-up and inspection.

Matter of fact, the check-ups began even before there *were* any forgings. The steel was subjected to thorough metallurgical analysis long before it reached the forging hammers. Then, at every step along the route, the job received another careful going-over. Finally, after hardness tests, dimensional checks, and surface inspection, the finished drop forgings rated the "Passed Inspection" tag.

Every order of Bethlehem drop forgings must run this kind of obstacle race and clear every prescribed check-point. It is the customer's assurance of quality workmanship; an assurance of forgings he can accept and use with confidence.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation.
Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

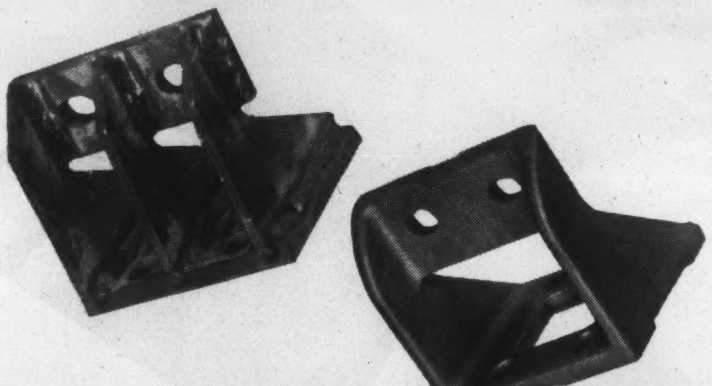
For more information, turn to Reader Service card, circle No. 474

Looking for a Better Way

...to cut costs
...improve appearance of your product?

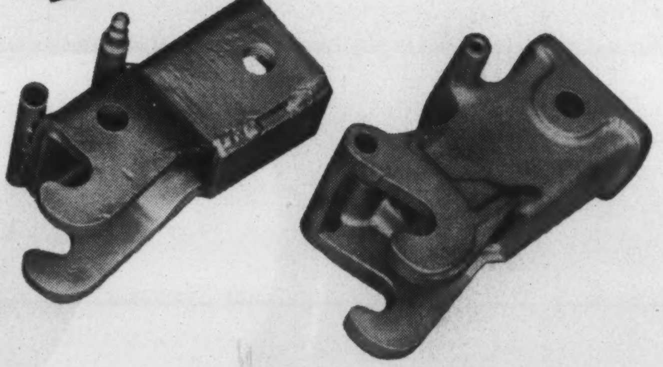
How about Malleable?

Malleable Iron's outstanding characteristics—toughness, ductility, ease of machining—command your consideration when you search for better ways to produce your product or its components. Here are two more examples of simplification and cost reduction.



A tractor fuel tank support was formerly made up of 5 pieces. The Pearlitic Malleable casting saves 40% for the manufacturer . . . improves appearance 1000%!

This implement coupler now looks better as a standard malleable casting, and is produced at much lower cost. It was formerly an assembly of 4 pieces entailing 7 costly operations.



Examples similar to these are plentiful. But more and more items are *designed* for Malleable as engineers realize (or remember!) its many advantages. . . Have you seen our "Value Analysis" brochure? Write for your copy, today.

Consult a malleable foundry engineer at the drawing board stage.

Malleable FOUNDERS' SOCIETY

1800 Union Commerce Building
Cleveland 14, Ohio

For more information, turn to Reader Service card, circle No. 481

Can Polyester Resins Be Cured by Radiation?

Can polyester plastics be toughened to a marked degree by irradiation as is the case with polyethylene resins?

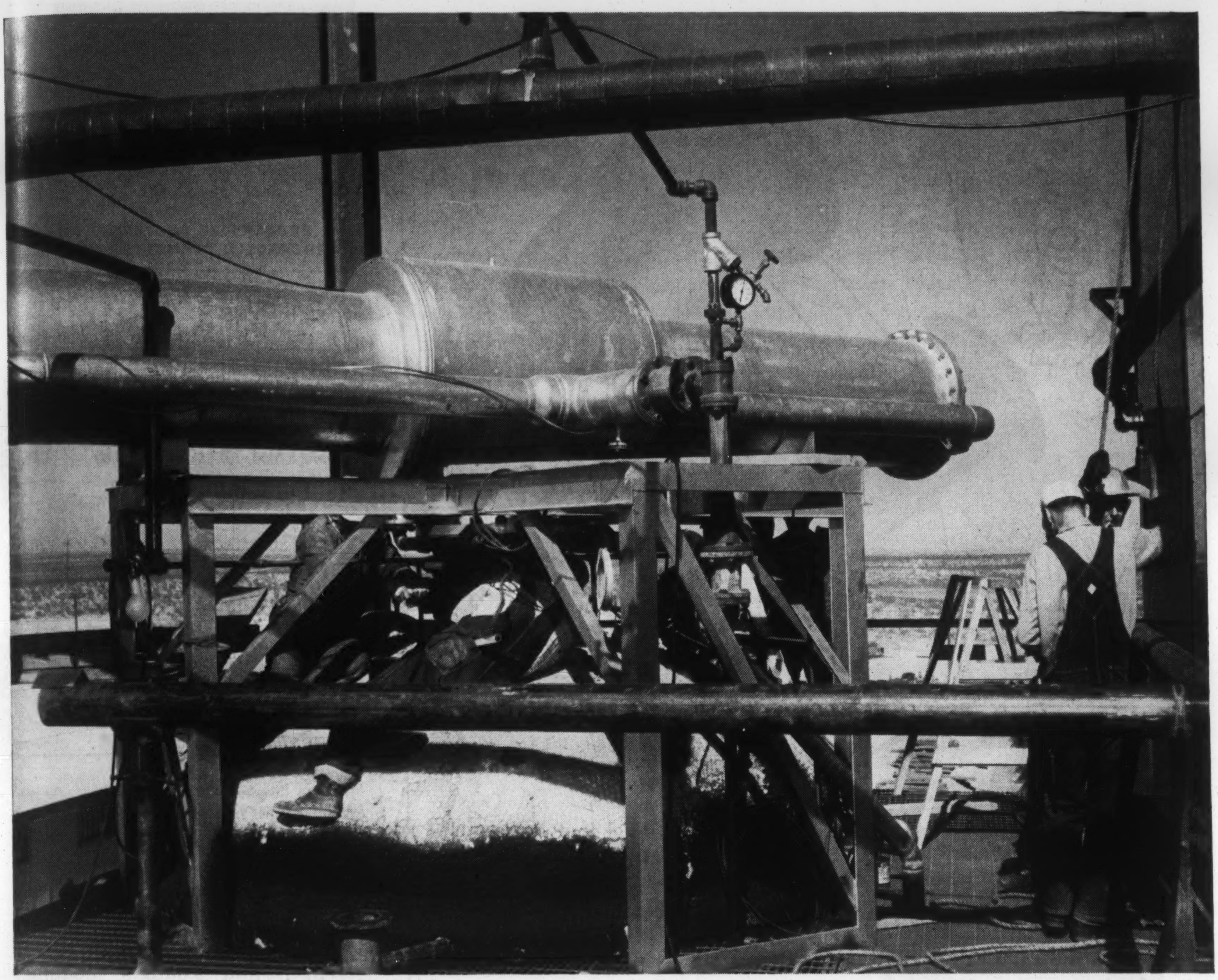
"No," say E. L. Colichman (Ramo-Wooldridge Corp.) and J. M. Scarborough (Atomics International, Div. of North American Aviation, Inc.). They say ". . . physical properties of either radiation crosslinked or radiation cured polyester resins do not appear to be vastly superior to heat cured polyester resins." However, radiation curing could be valuable in special applications where high purity material (without peroxide catalyst) is required or where heating is undesirable.

The two scientists arrived at their conclusion after an extensive investigation into the effects of radiation processing of unfilled polyester resins. Objects of their research was to learn: 1) if heat cured unfilled polyester plastics could be improved by radiation; and 2) if radiation curing of polyester resins would yield rigid compositions that are superior to those obtained by conventional heat curing methods. Details of their work may be found in the Mar '58 issue of the *Journal of Applied Chemistry* (British).

Treating cured resins

Commercially available polyester resins representing styrene- and diallyl phthalate-modified types were investigated. The two types of resin were heat cured and radiation processed in a MTR Gamma Facility Canal at dosages of 1.0 x 10^6 to 5.0 x 10^7 r. All samples were tested for hardness, heat distortion point and tensile strength; Young's modulus was calculated from stress-strain curves.

Test results show that the physical properties of diallyl phthalate-modified resins, with the exception of Young's modulus, are not



Erecting a crystallizer at a potash refinery in Carlsbad, N. M., operated by Pacific Coast Borax & Potash Co. This is one of seven crystallizers that were shop- and field-fabricated, then field-assembled by welding. They were not stress-relieved or heat-treated. There has been no stress-cracking in the nine months these units have been in service at the potash refinery.

NEW Ampco Metal Grade 8 stops stress corrosion cracking!

Important changes have been made in Ampco Metal Grade 8! It's *entirely new*—and completely obsoletes old ideas about fabricating copper-base alloy equipment to handle steam and corrosive media at elevated temperatures.

Now, with new, patented Ampco Metal Grade 8, you can . . .

1. Field-fabricate *without stress-relieving!*
2. Make field repairs, changes, and alterations *without heat treatments!*
3. Readily weld with any electric welding process! A. No pre-heat. B. No post-heat. C. No hot-short cracking!

At one major oil refinery, field-assembled piping of Ampco Metal Grade 8 has handled hot sulphuric-acid sludge for a year and a half without stress-cracking. Driers in a paper mill have handled 350° F steam at 125-lbs. pressure for more than a year without stress-cracking.

Let us prove it to you. Talk to your Ampco field engineer. Or write for details. *Ampco Metal, Inc., Dept. MDE-5, Milwaukee 46, Wis. (West Coast Plant: Burbank, Calif — Southwest Plant: Garland [Dallas County], Texas).*

AMPCO®

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RIVETS
TUBULAR RIVET
SPLIT RIVET
SELF-PIERCING RIVET
SHOULDER RIVET
TAPPED RIVET
Chicago Rivet
RIVETS
RIVETS
RIVETS

TIME TO LOOK AT COSTS

You need the answers to such questions as:

"Can a TUBULAR RIVET replace a solid rivet, screw, or bolt and thereby accelerate production?"

"Would a SPLIT RIVET with a decorative head improve product appeal?"

"Should a SELF-PIERCING RIVET be used and eliminate a drilling operation?"

"Can a cold headed part such as a SHOULDER RIVET serve as a fastener and also provide a bearing surface?"

"Would a TAPPED RIVET, made to receive a screwed-on assembly, simplify field service?"

These are typical questions asked of Chicago Rivet engineers because keen competition today makes necessary re-examination of production methods. No matter how complex or how simple your fastening problem may seem to be, get the cost saving advice that Chicago Rivet engineers can give. Send blueprint or sample assembly—no obligation.

There are Chicago Rivet Machines that will set
1 4
2 5
3 6
Tubular or Split Rivets At a Time

Chicago Rivet & MACHINE CO.
965 S. 25th Ave. · Bellwood, Ill. (Chicago Suburb) · Branch Factory: Tyrone, Pa.

FOR YOUR FILES—Rivet catalog describing 1388 standard tubular and split rivets and 26 single and multiple automatic rivet setters.

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PROPERTIES OF RADIATION-PROCESSED POLYESTER RESINS

Polyester Type ➡	Styrene	Diallyl-phthalate
AFTER HEAT CURE[a]		
Tensile Strength, psi	8100	8950
Heat Dist Point, F	190	268
Barcol Hardness	51	58
Young's Mod, 10^5 psi	3.65	3.15
AFTER RADIATION PROCESSING[b]		
Tensile Strength, psi	9583	8200
Heat Dist Point, F	201	270
Barcol Hardness	49	55
Young's Mod, 10^5 psi	3.96	3.65
AFTER RADIATION CURE[c]		
Tensile Strength, psi	9160	—
Heat Dist Point, F	176	—
Barcol Hardness	46	—
Young's Mod, 10^5 psi	3.98	—

[a] Cured 3 hr at 115 F.
[b] Gamma dosage of 1.0 x 10^7 r.
[c] Gamma dosage of 4.0 x 10^6 r.

improved by radiation processing. On the other hand, heat cured styrene-modified resins are improved by about 20% in tensile strength and Young's modulus; irradiation produced no significant changes in hardness and only small increases in heat distortion point.

In vinyl-modified polyesters it appears that the degree of cross-linking with the vinyl modifier is sufficient after heat cure to warrant no further processing by radiation.

Treating uncured resins

In curing polyester resins by radiation, Colichman and Scarborough found that completely cured samples could not be obtained with gamma dosages below 1.0 x 10^6 r. Styrene-modified resins can be completely cured by radiation at room temperature with gamma dosages of 5.0 x 10^6 to 1.0 x 10^7 r, with gelation beginning at about 5.0 x 10^5 r. Diallyl phthalate-modified resins require a dosage of 1.0 x 10^7 r and higher for complete cure, with gelation beginning at about 1.0 x 10^6 r.

Radiation-cured samples did not

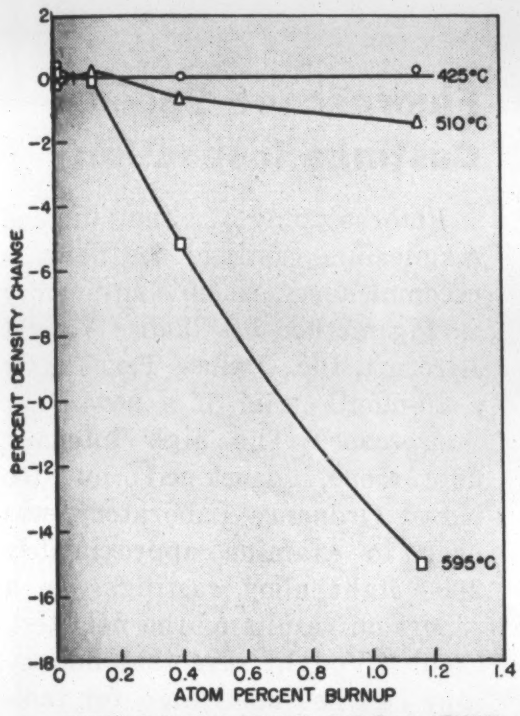
furthering creative technology at
The KNOLLS ATOMIC POWER LABORATORY

The significant relationship between advances in materials and processes, and advances in nuclear propulsion systems has generated a continuous program of original investigations in metallurgy and ceramics at The Knolls Atomic Power Laboratory.

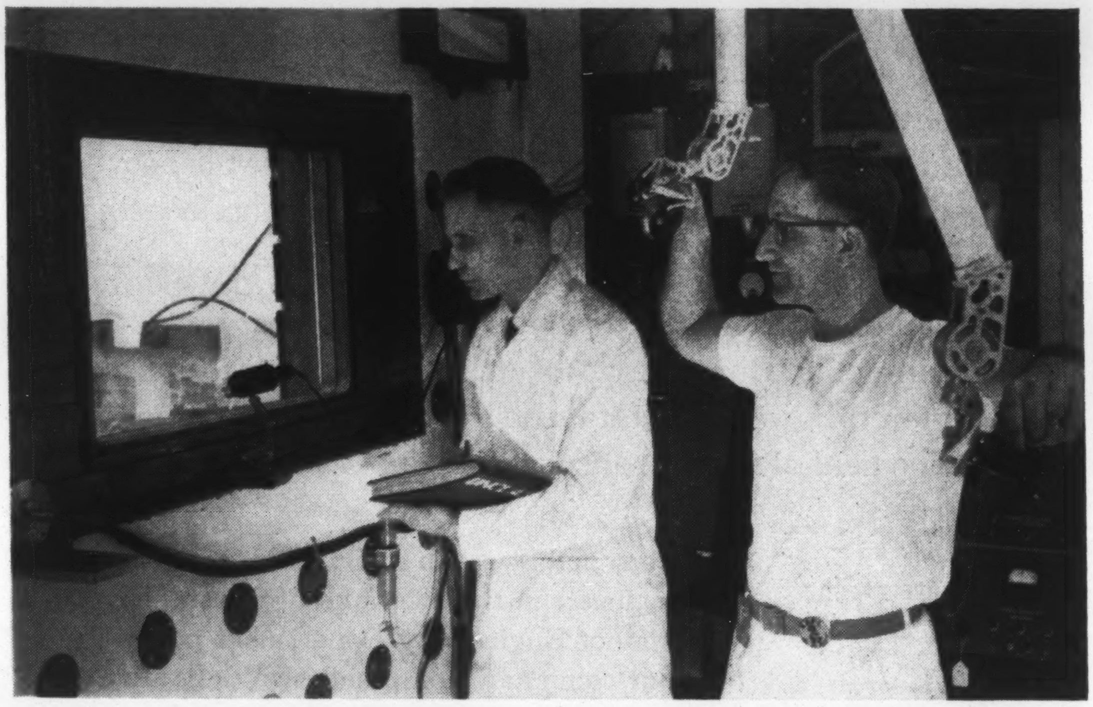
Currently the Laboratory is working toward the design of power reactors for operation at higher temperatures and with higher fuel burnups. A typical materials problem is the swelling and blistering of fuel elements caused by the agglomeration of inert gases (Kr and Xe) formed during nuclear fission.

• • •

An example of the physical-metallurgical studies now under way in this area is the experimental work described below.



DENSITY CHANGES IN ZIRCALOY CLAD 8 w/o URANIUM-ZIRCONIUM ALLOYS ON POSTIRRADIATION ANNEALING-



Dr. W. V. Johnston (left) recording data at post irradiation annealing cell.

POST-IRRADIATION ANNEALING OF URANIUM-ZIRCONIUM ALLOYS

To obtain information on the agglomeration mechanism and the extent of damage experienced, specimens of an 8 wt % enriched uranium-zirconium alloy which had been irradiated to a maximum of 42% of the U-235 atoms fissioned were annealed in vacuum furnaces at 425, 510 and 595°C. Percent density changes were determined as a function of temperature at an annealing time of 500 hrs. As can be seen in the graph, specimens of all burnups were stable at 425°C but volume increases of up to 15% were obtained at 595°C.

Additional information on the amount and rate of Kr and Xe diffusion and release from the fuel elements has been obtained by using β and γ counting techniques. The effects of irradiation and annealing on the temperature of phase transformations and on alloy structures are being studied by measurement of electrical resistivity, and use of advanced metallographic techniques.

PROFESSIONAL OPPORTUNITIES

There are openings at the Laboratory for metallurgists and ceramists interested in development, application and fabrication of nuclear core materials. Degree is required; advanced degree and/or related experience preferred. (U.S. Citizenship) If you qualify, please send resume, including salary requirement, to: Mr. A. J. Scipione, Dept. 39-MQ.

Knolls Atomic Power Laboratory
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SCHENECTADY, NEW YORK

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A competent group of Bunting Sales Engineers in the field and a fully staffed Product Engineering Department put at your command, comprehensive data and facts based on wide experience in the designing and use of Cast Bronze and Sintered Powdered Metal Bearings and parts.

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contain a benzoyl peroxide catalyst. Cobalt-60 was used as a source of radiation.

The authors point out that a single set of comparable data does not necessarily indicate all changes that might take place in irradiated polyester resins.

Fluoroscope Speeds Castings Inspection

Fluoroscoping of aluminum and magnesium castings for flaws is recommended as a time and money saving method by Chance Vought Aircraft, Inc., Dallas, Texas after a 20-month trial of a new Navy fluoroscope. The high intensity fluoroscope, developed by the Naval Ordnance Laboratory, was used to examine approximately 2000 light alloy castings. In a report on results of the field test, Chance Vought says that fluoroscopy can be substituted for radiography in certain applications.

Fluoroscopy costs considerably less than other x-ray methods, the survey found. For instance, it costs 16¢ to inspect a casting by fluoroscope and 80¢ by other x-ray methods. The report said that fluoroscopy lends itself well to quick inspection of weld beads, cracks, undercuttings, inclusions and gas holes in aluminum and magnesium castings. In addition, the report said that fluoroscopy would probably be far superior to other x-ray inspection methods for stainless steel brazed assemblies.

Other News . . .

Ferrous metals

▶ Normalized enameling steel in coil form is now being produced for the first time in volume at U. S. Steel's Irvin Works, Dravosburg, Pa. The company says previous production of enameling steel was limited to cut sheets. The steel, called Vitrenamel,

Experience—*the added alloy in* **A-L Stainless, Electrical and Tool Steels**

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With know-how and experience gained over the years, Allegheny Ludlum keeps little of it secret: it offers the most complete selection of literature available anywhere.

Literature, designed to help you learn more about Allegheny Stainless and how it can improve your product, is just one help offered by Allegheny Ludlum. You also get the best assistance from trained salesmen and technicians, ready to help you on your specific problem.

All this service is available through your Allegheny sales engineer. Call him today. Or, as a starter, write for the publication list describing the over 150 technical pieces made to assist you.

Allegheny Ludlum Steel Corporation, Oliver Bldg., Pittsburgh 22, Pa. Address: Dept. MM-5.

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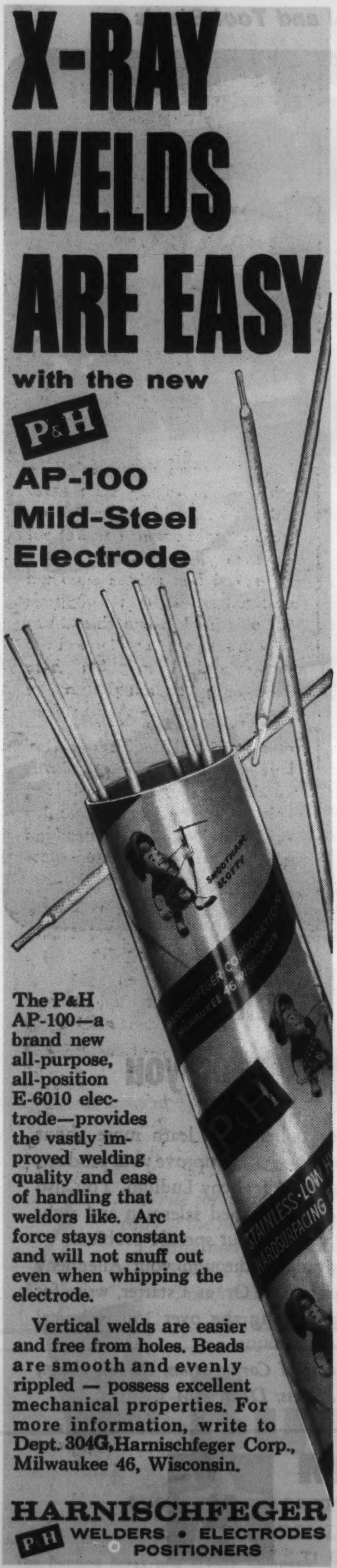


X-RAY WELDS ARE EASY

with the new P&H AP-100 Mild-Steel Electrode

The P&H AP-100—a brand new all-purpose, all-position E-6010 electrode—provides the vastly improved welding quality and ease of handling that weldors like. Arc force stays constant and will not snuff out even when whipping the electrode.

Vertical welds are easier and free from holes. Beads are smooth and evenly rippled — possess excellent mechanical properties. For more information, write to Dept. 304G, Harnischfeger Corp., Milwaukee 46, Wisconsin.

HARNISCHFEGER
P&H WELDERS • ELECTRODES POSITIONERS

For more information, circle No. 430

is available in 16 to 22 gage and in widths from 24 to 60 in.

Nonferrous metals

▶ A titanium alloy (Ti-6Al-4V) is now being marketed by Titanium Metals Corp. of America with guaranteed and certified oxygen content. According to the producer, no charge is made to the customer for certification. The alloy is available in bar and billet form.

▶ Cadmium strip and foil is now in commercial production at American Silver Co., 36-07 Prince St., Flushing 54, N. Y. The company says it can supply the strip and foil in widths from 4 to 6 in. and in thicknesses from 0.300 to 0.0005 in.

Nonmetallics

▶ A glass fiber thermal insulation for heating and air conditioning units has been introduced by Ehret Magnesia Mfg. Co., Valley Forge, Pa. Known as Therma-K, the insulation is supplied in three forms: pipe cover, duct liner and outside duct liner.

▶ Self-adhesive felt, pre-cut in a wide variety of shapes (circles, rectangles, squares, strips) and sizes, is now available from W. H. Brady Co., Milwaukee, Wis. The felt is particularly useful for dust and weather seals, thermal barriers and shock absorbers.

Finishes

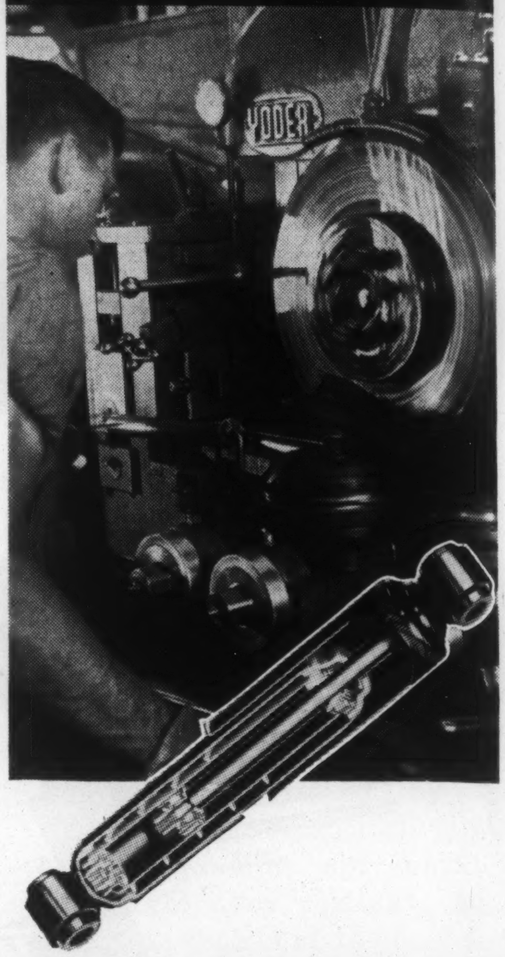
▶ A new coating used in conjunction with vacuum metallizing has been introduced by Bee Chemical Co., Chicago 33. Designated M-246H, it cures at 180 to 290 F and is particularly useful in the vacuum metallizing of soft metals. It can also be used in the vacuum metallizing of such thermosetting plastics as phenolics and ureas.

▶ A plastics coating has been developed by Protective Coatings, Inc., Tampa, Fla., to provide strength, and weather and chemical resistance, to polystyrene foams. Called Stryrokote, the coating cures at room temperature to a hard, glass-like finish.

Joining materials

▶ An improved Nylok fastener has been introduced by Groov-Pin Corp., 1132 Hendricks Causeway, Ridgefield, N. J. for joining metals to themselves and to other materials. The fastener, available in carbon and stainless steel and in brass, is said to tap its own threads in cored or drilled holes. A nylon plug locks the fastener against severe vibration.

Monroe Shock Absorbers rely on Precision Performance of YODER TUBE MILLS



After 15 years of continuous operation the Yoder Type-M Electric-Resistance Weld Tube Mill shown here, is still producing precision tubing for the Monroe Auto Equipment Co., Monroe, Michigan. Yoder produced tubing is the basic component of the famous "Monro-Matic" shock absorber. Measuring 2 1/64" outside diameter (plus several other sizes) the tubing is made from 22 gauge strip in one continuous operation . . . it is automatically cold-roll formed, welded and cut to pre-determined lengths.

This typical installation of a Yoder tube mill exemplifies the accuracy, dependability and production economies of Yoder-made tubing. If your business requires pipe or tubing, ferrous or nonferrous, in sizes from 1/4" to 26" diameters, there is a Yoder mill designed to produce it economically, efficiently and accurately.

THE YODER COMPANY
5546 Walworth Ave. • Cleveland 2, Ohio

Check into the many cost-saving advantages of operating a Yoder pipe or tube mill . . . write for the fully-illustrated 88-page Yoder Tube Mill Book . . . it is yours for the asking.

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ENGINEERING YODER MANUFACTURING
PIPE AND TUBE MILLS
(ferrous or non-ferrous)

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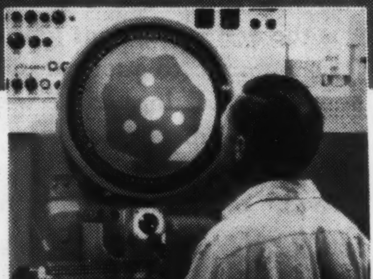

How many gages to inspect these parts?

Just one—if it's a Kodak Contour Projector.

Auburn Plastics, Inc., of Auburn, N. Y., a venerable custom molder, produces a wide variety of component parts for various manufacturers. Formerly this firm needed many mechanical gages to make necessary quality control checks.

A *Kodak Contour Projector* eliminated the expense of buying such gages—amounting in *one instance to a saving* of *$5,000.*

In a fiercely competitive business, Auburn Plastics, Inc., can submit *lower* bids because of savings permitted by *optical gaging*. The company effects additional economies by using its Kodak Contour Projector to inspect *tools* and *dies* as well as manufactured components. In all cases the projector permits gaging of angles, radii, holes and other dimensions—at a glance.

If you have an inspection problem involving myriad small parts, you can do the job easily and inexpensively with a Kodak Contour Projector. Inspection is a matter of comparing the projected image of the part with a chart gage on the screen. You inspect different types of parts simply by changing chart gages. Operators need little training.

For additional information or to arrange for a demonstration of any of the 6 Kodak Contour Projector models, write to:

Apparatus and Optical Division

EASTMAN KODAK COMPANY, Rochester 4, N. Y.

the KODAK CONTOUR PROJECTOR

With this Kodak Contour Projector Auburn Plastics, Inc., accurately gages a great variety of parts down to .001". Operator can easily measure angular dimensions on cams and keys, threaded mold components, center-to-center dimensions on parts and tools.

Kodak
TRADEMARK

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Nuclear Graphite is a Specialty at GRAPHITE SPECIALTIES CORP.

• High strength, fine texture and extra pure grades of Graphite Specialties graphite are available for lowest neutron-capture cross section. In addition, high scattering cross section and increasing strength at high temperature makes this material suitable for use in nuclear reactors as moderator, reflector, fuel elements, structural parts and piping.

• Graphite Specialties Corp. also furnishes custom formulated grades of graphite for mechanical, metallurgical and processing applications, as well as for high temperature electric furnaces.

• "Graph-I-Tite" is one of the standard formulations available. It is the first impervious graphite. It is immune to thermal shock, non-contaminating, not wetted by molten metals, and is unaffected by practically all corrosives, even at temperatures above 1,000°F.

• Most types of Graphite Specialties graphite can be molded, extruded or machined to close tolerances, and are available as finished components, or in rod tube, sheet, block or rough extruded or molded form.

• Don't let old fashioned materials restrict your thinking. If you have an "ordinary" materials problem, or one such as heating dry chlorine up to 5000°F., write to GRAPHITE SPECIALTIES CORPORATION, 64th & Pine Avenue, Niagara Falls, New York.

For more information, circle No. 412

MATERIALS
AT WORK

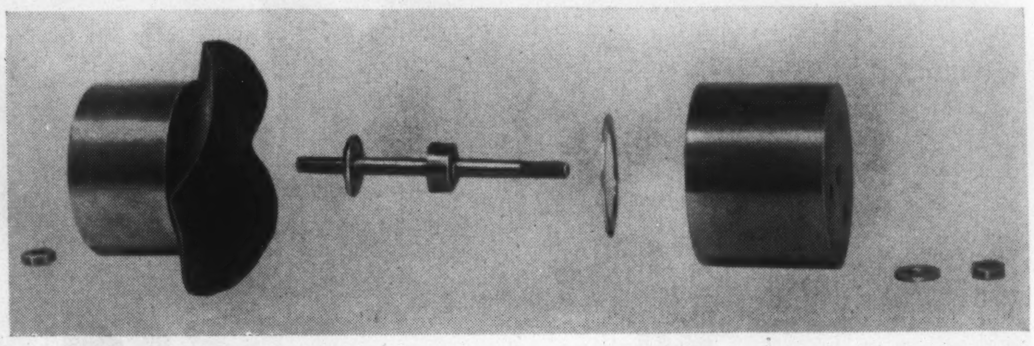
Viton—cont'd from p 12

temperatures of 400 F and higher, and resistance to lubricants, fuels and hydraulic fluids.

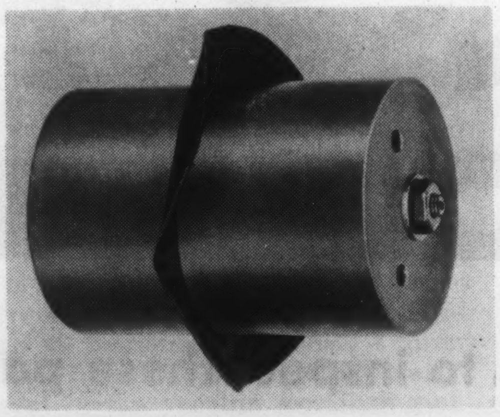
Because Viton offers an excellent combination of high temperature properties, it has become a valuable material for several different applications. The most common is o-ring seals and packings; other uses include high temperature hoses, rolls and coated fabrics. The material is also available as sealing strips for gaskets, caulking compounds, adhesives, protective coatings, linings, etc. Some of the more important applications are shown in the accompanying photos.

New technical data is given in this month's "What's New In Materials," p 166.

Phenolic Adhesive Resists Fuels



Exploded view *showing diaphragm support and seal and . . .*



. . . assembled unit.

The replacement of a Buna N-base adhesive by a phenolic resin-base adhesive has eliminated the problem of corrosion in a water injection regulator used on aircraft engines. The adhesive is used in the regulator to produce a tight bond between the seal and the diaphragm support (see photo).

A previous design called for the seal to be pinched into the seat. However, Pratt & Whitney Aircraft found that better diaphragm retention and less distortion could be achieved by adhesive bonding the seal to the seat. Unfortunately, the Buna N-base adhesive could not stand up under the attack of certain aircraft fuels which contain as much as 30% aromatics.

The phenolic-base adhesive resists not only aircraft fuels of this type, but alcohol and piston engine oil as well—even at operating temperatures in the range –65 F to 400 F. According to the supplier, Raybestos - Manhattan, Inc., the phenolic adhesive may be used for rubber-to-metal, plastic-to-metal, metal-to-metal and friction material bonding.

Eight Die Castings in New Recorder

In order to produce what Wollensak Div., Revere Camera Co., considers the "smallest and lightest" portable hi-fi tape recorder on the market, standard concepts of recorder design were reversed and the unit was built from the inside out — mechanism first, housing last. As a result, many of the die cast housing sections

120,000 of these detonator plugs

equal

one 73 lb. bumper strip

both are products of

ORCO

CUSTOMEERING

The precision pigmy component weighs less than 3/10 of a gram and is an important part of a delicate detonator assembly. The 73-lb. bumper strip is a protective part of a "Dodgem" car in amusement parks.

Big difference in size and application? Sure, but Ohio Rubber is recognized as a producer of "customeered" parts made from rubber, synthetic rubber, silicone rubber, polyurethane, and flexible vinyl, in *all sizes,* for any application, and whether molded, extruded, or bonded to metal.

From design through electronically controlled compound mixing and production facilities in four plants, Ohio Rubber's integrated set-up is prepared to handle your most exacting rubber and vinyl component requirements. Let ORCO engineers help on your next problem. See how ORCO CUSTOMEERING can work to your greater advantage.

Send for free booklet "Component CUSTOMEERING rubber and vinyl parts."

THE OHIO RUBBER COMPANY

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If your project has heat, abrasion, corrosion, chemical or other deteriorating factors present, then McDANEL specially-developed ceramics could be the answer. Instrument manufacturers, scientists, physicists, research and development engineers, and specialized producers are applying McDanel ceramics to a wide variety of difficult applications with good success. McDANEL ceramic engineers work with you to develop designs, special dies, even new processes to suit your particular need. Try ceramics.

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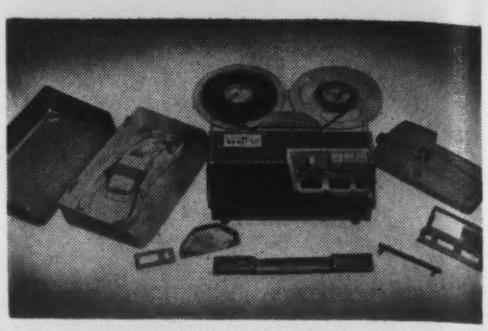


Die castings *in portable tape recorder function as housing and integral parts of unit itself.*

serve as integral parts of the unit itself.

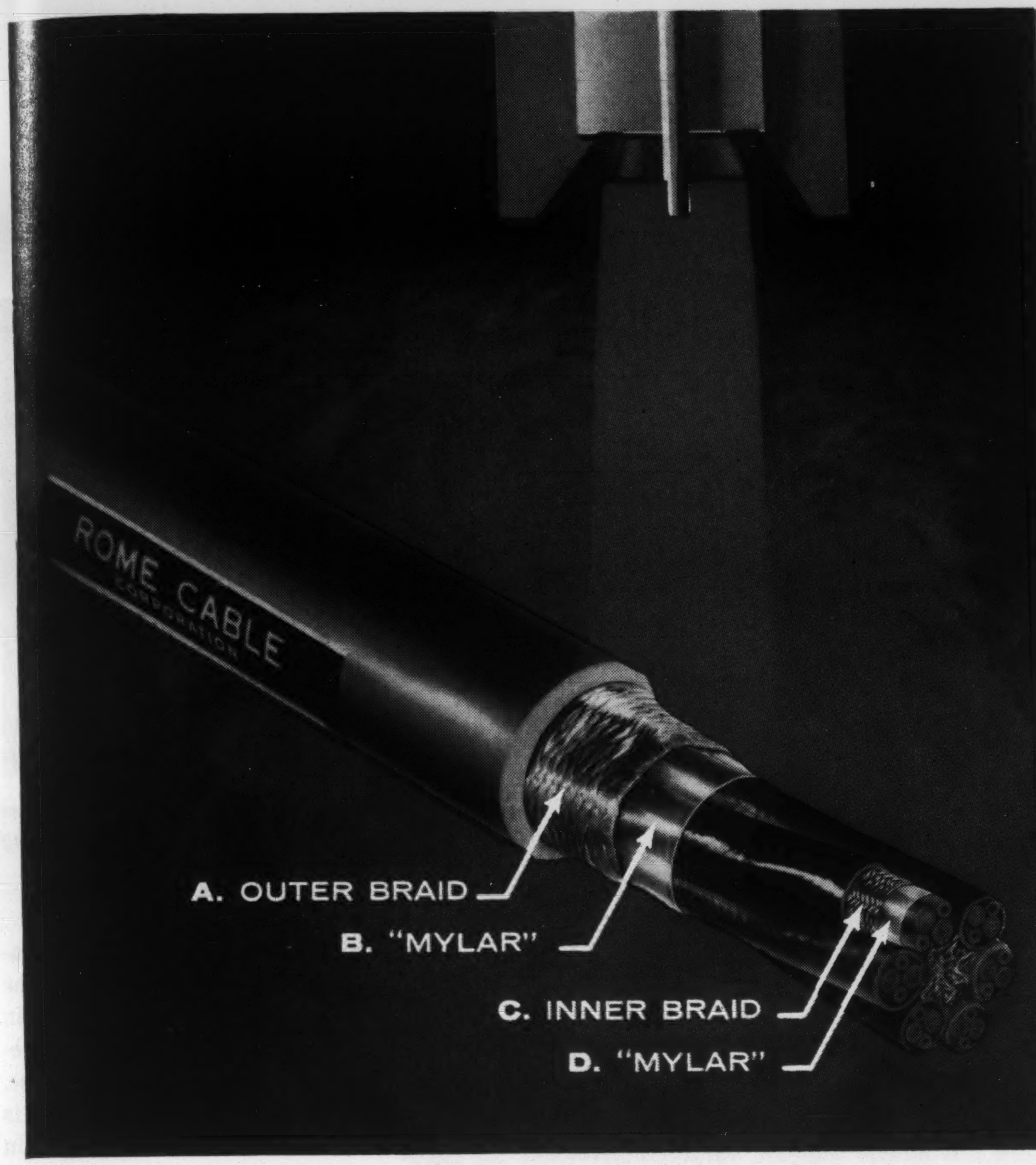
The decision to use die castings instead of other materials such as plastics was dictated by requirements of strength, appearance and the necessity to maintain close tolerances. In all, eight die castings are used—seven aluminum and one zinc. The castings require little machining and are finished with either chromium plate or baked enamel.

The eight die castings used in the unit are: two side castings, recording head cover, clean-out cover, counter bezel, key bezel (zinc), handle and case cover (see photo). The two side castings are cast with a groove to simplify masking during finishing; the groove not only reduces the cost of applying the finish, but assures closer fitting of parts afterwards. The top cover is cast in a single impression die with bosses to which steel clips are attached to hold the microphone and cord in place. The handle is made in a double impression die, and the depressed lettering is later filled with black enamel.

The complete recorder weighs about 18½ lb and measures 6½ x 10½ x 11¾ in.

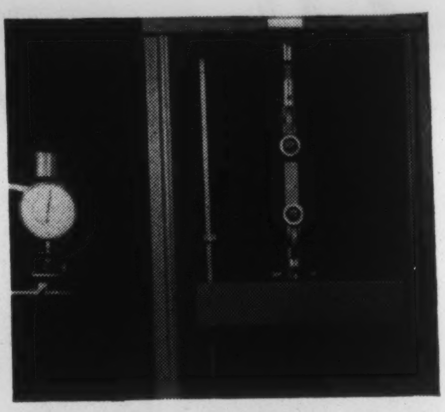
Stainless Water Gage Won't Lose Visibility

A new water level gage, consisting of a nonmagnetic stainless steel tube enclosing a metal float

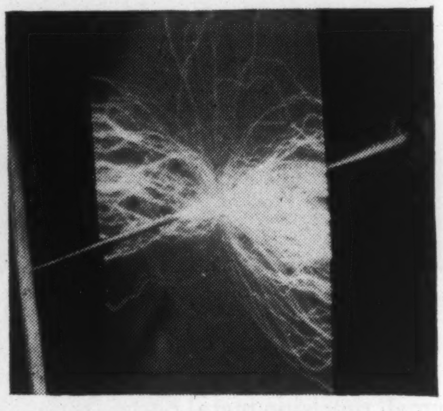


PROPERTIES OF "MYLAR"

"Mylar" offers a unique combination of properties that may help you improve performance and lower costs of *your* product. Here are two of the many important properties for evaluation.



HIGH TENSILE STRENGTH. "Mylar" is strong and durable. Instron Tester shows an average strength of 20,000 psi. It's dimensionally stable . . . resists moisture.



HIGH DIELECTRIC STRENGTH. Average of 4,000 volts per mil . . . average power factor of 0.003 to 60 cycles . . . dielectric constant above 3.0 at 72°F., 1,000 cycles.

Rome Cable reports . . .

Du Pont Mylar® helps eliminate reject problem in manufacture of cable for "Titan" ICBM

PROBLEM: In designing its instrumentation cable for the "Titan" ICBM project, Rome Cable Corporation wanted a thin, abrasion-resistant tape to protect the insulated conductors from possible puncture by loose strands of the tin-copper braid (See C in illustration). They were also searching for a thin, heat-resistant core binder tape to prevent possible puncture from the outer braid (See A) during extrusion of the cable jacket.

SOLUTION: A tape of Du Pont "Mylar" polyester film for both applications (See B&D). Reason: "Mylar" has the desired balance of mechanical and electrical properties . . . it's tough, abrasion- and puncture-resistant, even in thin gauges. "Mylar" has a high melting point . . . runs well on existing machinery.

RESULTS: The two tapes of "Mylar" eliminated shorted cables due to puncture from loose strands of metal. Solving this problem has helped Rome Cable stabilize production, save money on time and materials and produce a cable that assures better performance and greater reliability in the ICBM.

How can "Mylar" help you? Whether you manufacture heavy-duty cable or tiny capacitors, it will pay you to evaluate the combination of properties found only in "Mylar". And when figured on an area basis, this tough, thin polyester film will often *cost less* than your present insulating material. For more detailed information, send in coupon.

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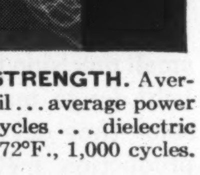
. . . THROUGH CHEMISTRY

DU PONT
MYLAR®
POLYESTER FILM

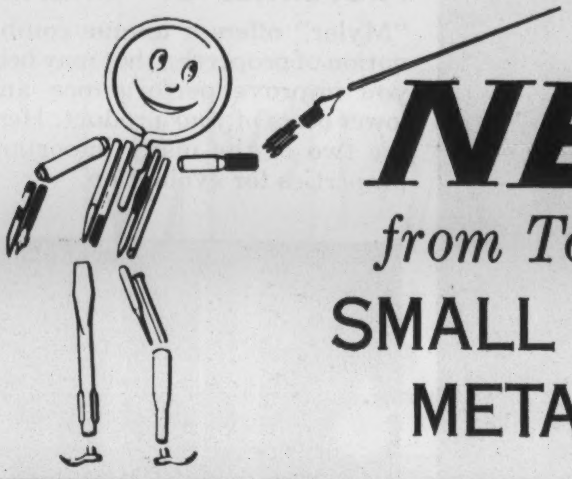
*"MYLAR" *is Du Pont's registered trademark for its brand of polyester film.*



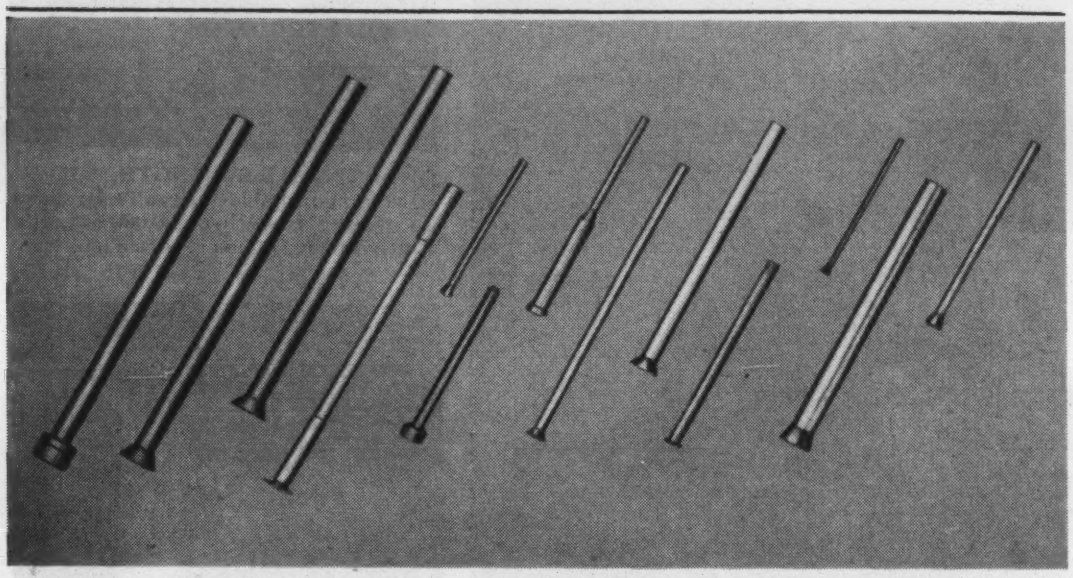
E. I. du Pont de Nemours & Co. (Inc.)
Film Dept., Room MM-5, Nemours Bldg., Wilmington 98, Del.
Please send the new booklet listing properties, applications and types of "Mylar" polyester film available (MB-11).

Application____________________
Name____________________ Title____________
Company____________________
Address____________________
City____________________ State____________

For more information, turn to Reader Service card, circle No. 500



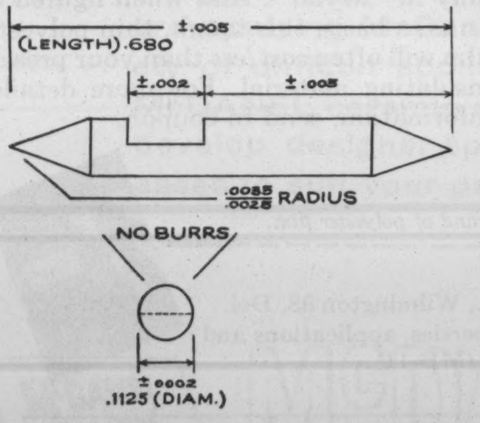
NEWS
from Torrington on
SMALL PRECISION
METAL PARTS



Here at Torrington, our "Specialties" machines are constantly at work producing an endless variety of custom-built small precision metal parts. Our engineers help design many of these parts, at the same time developing the most efficient production methods to solve our customers' problems.

For example, one manufacturer recently needed perforating punches with an upset head (see photo above). His own facilities were inadequate for the job . . . specifications called for close body tolerance, grinding, precision heading, hardening and annealing. The punches were to be made from tool steel and produced without flash to allow proper seating. Torrington engineering and production facilities solved his problem.

Another—the volume production of timer parts with low cost a critical factor.



For this job, Torrington developed special high-speed equipment to provide automatic end turning and cross milling in a single operation. The result—a high-quality part produced at low unit cost.

Whatever the part, varying degrees of strength, ductility, hardness, toughness, magnetic or nonmagnetic properties are required to give it the exact qualities needed for its particular function. In Torrington's modern laboratories, highly experienced metallurgists and engineers are employed to insure that each precision metal part is produced by the most efficient process and to the highest standards required for its application. They'll be glad to help you on all metallurgical problems.

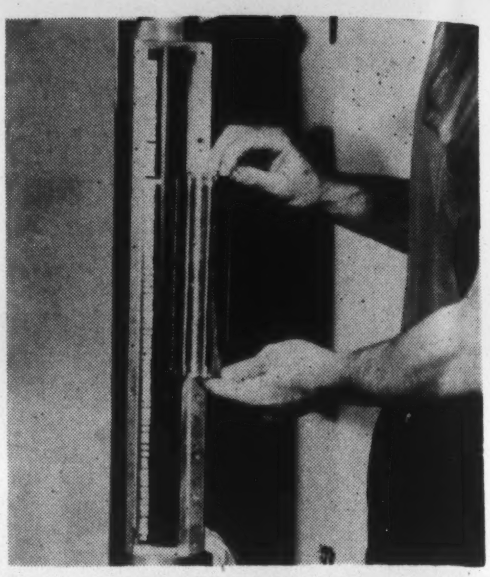
If you have problems involving custom-built small precision metal parts in large quantities, write direct to

The Torrington Company, Specialties Division, 777 Field Street, Torrington, Conn.

TORRINGTON SPECIAL METAL PARTS

Makers of Torrington Needle Bearings

For more information, turn to Reader Service card, circle No. 526



Nonmagnetic steel tube *encloses magnet which pulls white indicating reeds into view.*

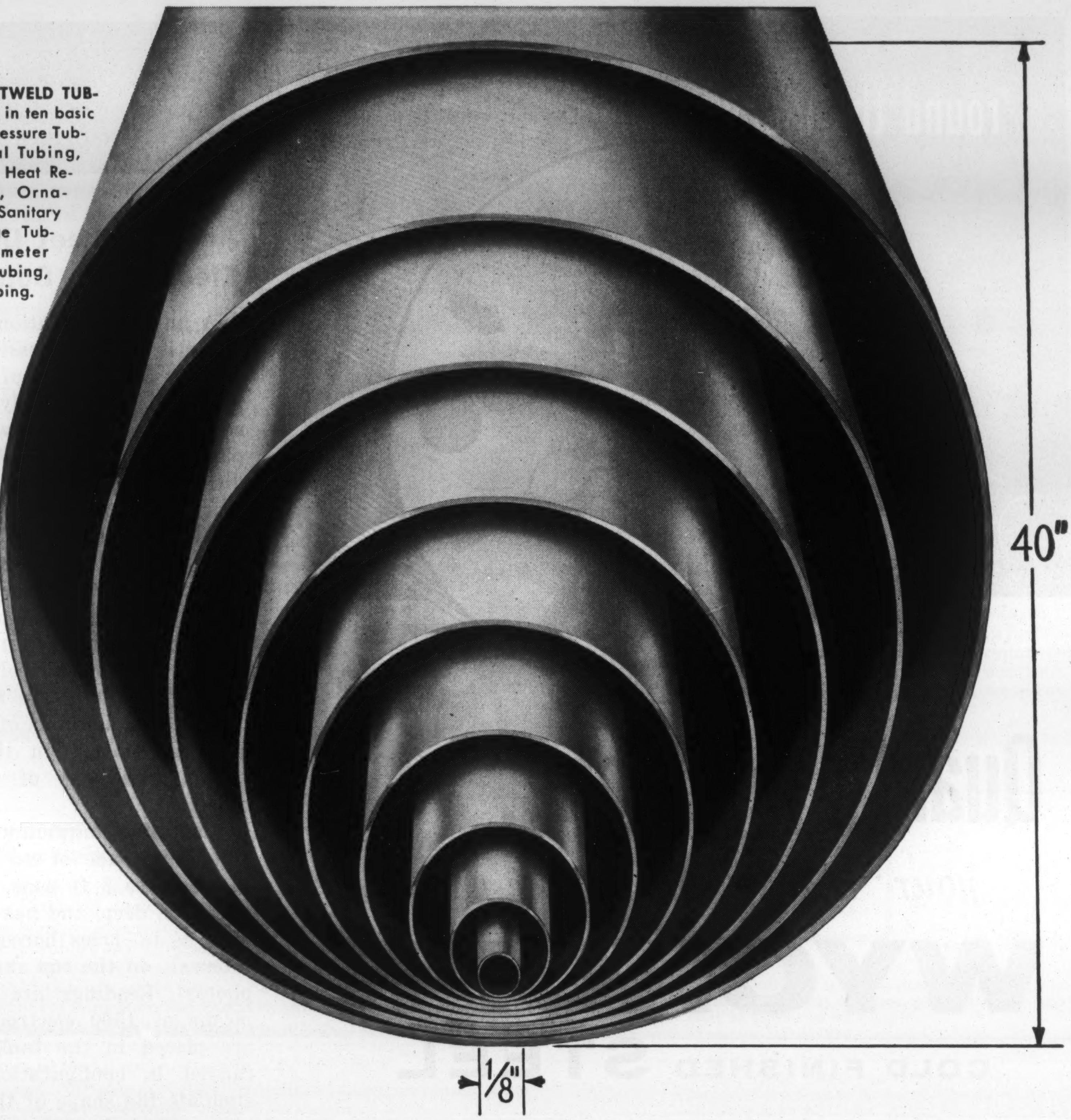
which carries a powerful permanent magnet, is said to be the "first major improvement in boiler gages in 150 years." Developed by Charles Engelhard, Inc. for the Navy, the instrument is similar to conventional gages in size and shape, but is said to have eliminated problems of leakage and poor visibility encountered with the previously used glass or quartz tubes.

In operation, the float rides up and down on the water in the tube, and the magnet acts through the tube walls upon a row of metal reeds mounted beside it. Each reed, which is painted white, can be pulled forward by the magnet so that it comes into view through a window in front of the gage. When the float moves again, the reed recedes out of sight.

In addition to serving as a visible indicator of the water level, the reeds can carry electrical contacts which operate automatic water controls or set off alarms.

(more Materials at Work on p. 188)

SOURCES of most engineering materials can be found in M/DE's *Materials Selector* reference issue, published last September. Properties of all materials are also given.



CONTOUR TRENTWELD TUBING is furnished in ten basic classifications: Pressure Tubing, Mechanical Tubing, Aircraft Tubing, Heat Resistant Tubing, Ornamental Tubing, Sanitary Tubing, Beverage Tubing, Large Diameter Tubing, Shaped Tubing, and Formed Tubing.

TRENTWELD tubing is equal in strength and has more uniformity than tubing made by any other method of manufacture

Trent offers tubing in sizes ranging from ⅛" to 40" O.D. and in a wide range of grades. These include: Hastelloy,* Zirconium, Zircaloy, Titanium and 19-9-DL grades. All are made by an exclusive welding process—Contour Trentweld®—which virtually eliminates the bead. Furthermore, by cold working and annealing after welding, Trent makes the weld equal in strength and corrosion resistance to the parent metal.

To insure that Trentweld tubing is of the highest quality attainable, a rigorous quality control program is carried out. Samples of each lot are tensile tested. Periodic tests — flattening, reverse bend, flare and flange, coil, and pressure — are conducted. Rigid corrosion tests are made on all lots intended for corrosive applications. When requested, a unique "single-wall" X-ray inspection is made as your final assurance of a sound, uniform product.

Why not take advantage of Trent *quality* when you order stainless or high alloy tubing? For further information, write for the Trent tubing handbook, Trent Tube Company, East Troy, Wisconsin.

**Trademark of Haynes Stellite Co.*

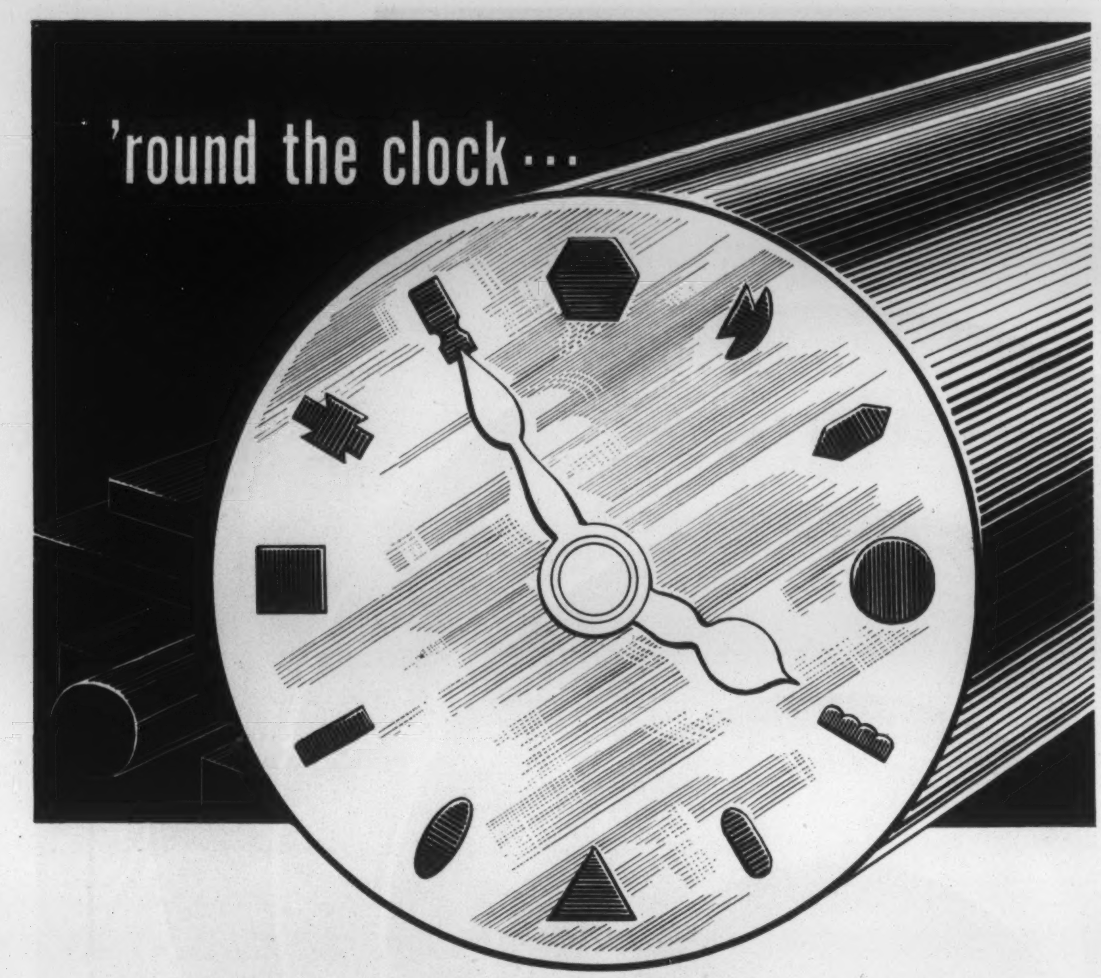
CONTOUR TRENTWELD

TRENT TUBE COMPANY

Subsidiary of Crucible Steel Company of America

GENERAL OFFICES: EAST TROY, WISCONSIN
MILLS: EAST TROY, WIS.; FULLERTON, CALIF.

For more information, turn to Reader Service card, circle No. 399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Quality Control...

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COLD FINISHED STEEL

Constant working qualities that save you time and money are the "pay-off" to you from Wyckoff ceaseless research and Wyckoff quality controlled products.

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Gateway Center, Pittsburgh 30, Pa.
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WYCKOFF STEEL PRODUCTS—Carbon, Alloy and Leaded Steels • Turned and Polished Shafting • Turned and Ground Shafting • Wide Flats up to 12" x 2" and 14" x 1¼" • All types of furnace treated Steels

For more information, turn to Reader Service card, circle No. 385

MATERIALS AT WORK

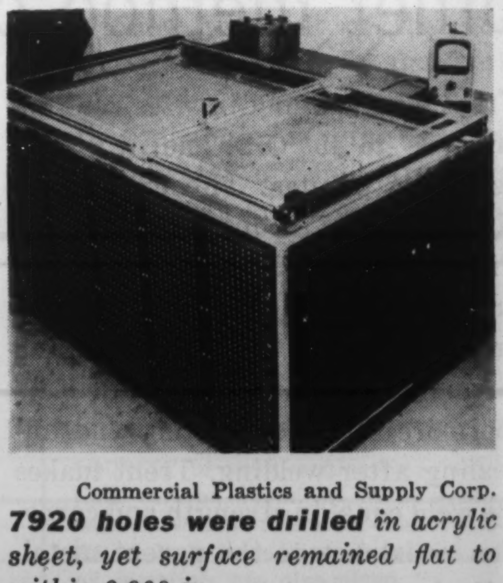
Acrylic Sheet Used in Electrolytic Computer

A unique application of acrylic sheet is making possible an extremely complex job of fact gathering in an electrolytic analog computer—a device which supplies information about heat conditions in the interior of nuclear reactors.

As designed by Nuclear Development Corp. of America, the computer solves these problems by setting up an analogous situation in which measurements of electric current and voltage in an electrolytic liquid are made comparable to conditions of heat flow and temperature in the corresponding locations of a nuclear reactor.

The tank containing the electrolyte is made of acrylic sheet. It measures 3 ft wide, 5 ft long and 3 in. deep, and has a total of 7920 ¼-in. holes bored at ½-in. intervals on the top surface (see photo). Readings are taken by means of 1500 electrodes which are placed in the tank and arranged in configurations which simulate the shape of the reactor core or fuel element under study.

After the holes are bored, stainless steel inserts are force fitted into the holes and the surface is finished by hand scraping and liquid polishing.



Commercial Plastics and Supply Corp.

***7920 holes were drilled** in acrylic sheet, yet surface remained flat to within 0.008 in.*

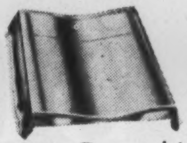
For more information, circle No. 468 ➤

Swedlow specializes in heat protection!

Silicones
Phenolics
Epoxies
Reflective coatings
Sheet materials
Molded parts
High temperature welded honeycomb c

The solution to your heat problem is in the following...

Swedlow's aluminum-metallized heat reflective laminates 1650°F



MINIMUM WEIGHT • MINIMUM BULK—By combining the principles of highly efficient reflectivity of aluminum-metallized surfaces with the low thermal conductivity of glass fabric reinforced plastic laminates, Swedlow's "—101" metallized coatings offer protection up to 1650° F. The metallic coating protects the base laminate from thermal degradation.

APPLICATIONS—In flat sheets, or molded into complex contours, these materials are suggested as highly efficient heat blankets for compartment insulation, valve protection, exhaust heat damping, and other applications where there is prolonged high temperature exposure.

Swedlow's silicone plastic laminates 650°F

Swedlow's X5G-138 and X5G-176 silicone base materials are available as flat sheeting or molded parts and offer protection up to 650°F.

Swedlow's X5G-138 provides maximum strength per unit of thickness and weight and is recommended for applications requiring flat sheets or simple contoured molded parts.

The X5G-176 laminate has slightly lower physical properties than X5G-138 but is recommended for applications requiring complex contours.

APPLICATIONS—Missile nose cones, exit cones, fins, stabilizers, adapter rings, closure rings, and similar uses. Applications in airstreams at missile speeds are possible.

Swedlow's high temperature welded honeycomb core /2500°F /2000°F

HIGH STRENGTH-WEIGHT RATIO • HIGH RIGIDITY-WEIGHT RATIO • HIGH VIBRATION DAMPING • HIGH FATIGUE RESISTANCE—The use of high temperature honeycomb core is expanding rapidly in a wide variety of aircraft and missile assemblies and parts, particularly where such parts experience high engine temperatures, aerodynamic heating, and corrosive environments. On your production line, use of honeycomb core assemblies reduces the number of parts, simplifies fabrication and assembly, reduces tooling, floor space and over-all costs per pound, and cuts repair and rework. Face sheets may be brazed to the core by the user for use at temperatures approximating 2000° F., or adhesives may be used if temperatures do not exeed 500° F.

APPLICATIONS—Wherever structural strength and corrosion resistance are required at extreme temperatures... with light weight.

600°F *Swedlow's high temperature phenolic plastic laminates*

STABLE PHYSICAL PROPERTIES UNDER HIGH TEMPERATURES—Swedlow's X4G-116 is a high-temperature phenolic laminate that offers unusual physical stability at high temperatures up to 600°F. It is available in flat sheets, and can be molded to complex contours.

APPLICATIONS—Fins, stabilizers, missile nose cones, adapter rings, closure rings, and similar applications. May be used in airstreams at missile speeds.

450°F *Swedlow's epoxy-plastic laminate*

Swedlow's X6G-141 epoxy-plastic laminate gives the user an electrical insulating material resistant to fracture and warpage in installation, with characteristics of very low moisture absorption and high physical strengths over a prolonged temperature gradient. Approved under MIL-P-18177. Conforms to NEMA standards for type G-3 materials.

APPLICATIONS—Air conditioning and heat distribution ducts. Winding barriers and ducting in transformers. Sheeting for circuitry installations. Dielectric capacitors for condensers. Terminal board and strip applications in electronic equipment. Coil spacers and relay bases in magnetic devices. Mounting plates, contact spacers and shielding for control devices.

Swedlow
PLASTICS COMPANY

Los Angeles, California
Youngstown, Ohio
Please refer to Dept 18

For short duration of time the temperatures given for the above materials may be raised appreciably. Each application must be considered individually.

Swedlow is continuing research in high-temperature materials of all types . . . reflective coatings, ceramics, plastics, metals.

A highly trained staff of engineers and technicians will be pleased to assist you on the use of these materials for high temperature service. Please contact the plant nearest you.

heat problems?

Announcing

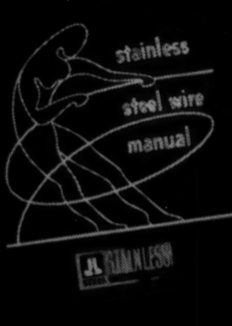
NEW SOURCE for stainless steel wire

J & L Stainless Steel Division's New Wire Mill Offers Wide Range of Wire Sizes

The increasing use of stainless steel wire in new product development, old product improvement and for experimental purposes has placed a new responsibility on the manufacturer of quality stainless steel.

To meet this growing need, J & L Stainless Steel Division is pleased to announce the opening of its new wire mill . . . to make available stainless wire in a wide range of sizes, finishes and coatings.

For data regarding wire, its properties and uses, consult our Stainless Steel Wire Manual. For special applications write in detail giving complete information about your requirements.



Wire now for your copy of J & L's new Stainless Steel Wire Manual.

Improve your Products with . . .

J&L STEEL STAINLESS

BAR • WIRE • SHEET • STRIP

Jones & Laughlin Steel Corporation

PRICES AND SUPPLY

...AT A GLANCE

1957 OUTPUT OF PIG IRON SET AN ANNUAL RECORD of 79,339,671 net tons. According to American Iron & Steel Institute, last year's production was 1½ million tons greater than the previous record of 77,790,000 tons set in 1955. In 1956, 75,960,000 tons were produced.

DU PONT'S DACRON POLYESTER FIBER MAY BE IN FOR SOME COMPETITION within the next year or two. According to recent reports, at least two other companies—Beaunit Mills, Inc. and Tennessee Eastman Co.—have developed polyester textile fibers that are beyond the laboratory stage. In fact, Beaunit has announced definite plans to put a 10-million-lb-per-year plant on stream sometime next year.

ZINC SMELTING HAS BEEN DISCONTINUED at Eagle-Picher Co.'s Henryetta, Okla. plant. According to John Wade, plant manager, resumption of operations will await an increase in zinc consumption. The plant was reactivated last November after a four month shutdown resulting from a contract dispute. At that time, Eagle-Picher said it was "gambling" on tariff increases to create greater domestic markets.

PYROCERAM IS NOW COMMERCIALLY AVAILABLE from Corning Glass Works. The new material, described as a crystalline ceramic (see MATERIALS IN DESIGN ENGINEERING, July '57, p 142), is being produced initially in the form of tubing and plate.

COILED STRIP STEEL OUTPUT HAS BEEN INCREASED by more than 100,000 lb per month at Jones & Laughlin Steel Corp.'s Aliquippa, Pa. plant. According to Jones & Laughlin, the new 44-in. semicontinuous hot strip rolling mill will produce strip steel up to 40 in. wide for use primarily in the manufacture of tinplate.

NEW CUTS IN THE PRICE OF HIGH DENSITY POLYETHYLENE have been made by W. R. Grace & Co. and Phillips Chemical Co. According to both companies, a 4¢-per-lb reduction—from 47¢ to 43¢—applies to all general molding and extruding grades.

A CUT IN NICKEL PRODUCTION of about 1250 tons per month has been made by International Nickel Co. of Canada. According to the company, the

◀ For more information, circle No. 427

world's largest nickel producer, even further cuts may be necessary ". . . unless business shows a quick upturn." Last year Inco produced about 145,000 tons, or approximately 60% of the total free world nickel output.

PRICE REDUCTIONS ON TWO GRADES OF SELENIUM have been effected by American Smelting & Refining Co. Common grade is now $7 per lb, down from $7.50, and high purity grade is now $9.50 per lb, down from $10.50. Canadian Copper Refiners, Ltd. also reduced its selenium prices to the same levels.

PRODUCTION OF COPPER HAS BEEN CUT 3500 tons per month by Kennecott Copper Corp. According to the company, the reduction is aimed at putting supply and demand "more nearly" in balance. In January, Kennecott decreased production by 3800 tons per month.

POLYSTYRENE PRICES HAVE BEEN REDUCED by Dow Chemical Co. Certain formulations of crystal are now 24½¢ per lb, down from 25¢; colored polystyrene is now 27½¢ per lb, down from 28¢.

IRON POWDER IMPORTS ARE CONTINUALLY DECREASING, according to Kempton H. Roll, executive secretary of the Metal Powder Assn. In 1956, about 22,500 tons of iron powder were produced domestically and about 10,000 tons were imported. In 1957, domestic production increased to almost 25,400 tons, and imports dropped to about 5000 tons.

DOW CHEMICAL CO. HAS ENTERED THE LIQUID EPOXY RESIN FIELD with the introduction of three basic resins which it says are designed to be of interest to the tooling, electrical, paint, adhesive, reinforced plastics and chemical industries.

A NEW TANTALUM-COLUMBIUM PILOT PLANT has been put into operation by U. S. Industrial Chemicals Co. The plant will produce between one and three tons of combined metals per month. According to USI, the two metals will be produced in approximately equal quantities although variations from 10% tantalum up to 60% tantalum are possible, depending upon the ore used.

GLASS-REINFORCED POLYESTER LAMINATE PRICES HAVE BEEN REDUCED by Glastic Co. According to a recent announcement, the 58¢-per-lb base price for Grade TS now applies to 300-lb quantities instead of the usual 2000-lb quantity. And Grade 618, used for Class B electrical insulation, has been reduced from 86¢ per lb to 76¢ per lb (for 2000-lb quantities).

Turn to page 194 for more "Prices and Supply"

ESCO CENTRIFUGAL CASTINGS MEET NUCLEAR SPECIFICATIONS

ESCO Spuncast®, a centrifugal casting process for making symmetrical, tubular parts, is especially adapted to the manufacture of nuclear stator shells, piping and scram rods, for atomic power installations.

The Stator shell (illustrated), used to make "canned" or hermetically sealed pump motor housings, is a 1,300-lb. Spuncast casting. The "built-in hole" saves countless hours of machining time as well as substantial savings in waste metal.

Cast to rigid specifications (MIL-S-18262, Class 1, 100% dye penetrant and radiograph inspected to ASTM E71 class 2, standard), these stator shells are typical of the exacting metallurgical jobs handled economically every day at *ESCO*. The Spuncast process is only one of several processes available at *ESCO*.

Call your nearest ESCO representative today for details. Ask for your free copy of "How to Cut Costs With ESCO Spuncast", a 12-page brochure, or write direct.

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For more information, turn to Reader Service card, circle No. 532

This part cast from a magnetic alloy, Hipernik®, cut production costs 80%.

CUT COSTS WITH INVESTMENT CASTING OF MAGNETIC ALLOYS

Many of today's alloys are difficult or impossible to machine or forge. Many magnetic parts and components are so intricate in shape that to machine them would require multiple set-ups. Investment casting minimizes machining costs, yet retains the magnetic properties you need.

Westinghouse can provide castings of high-nickel magnetic alloys that retain comparable magnetic properties of wrought materials. With value and cost analysis so important, consider precision investment casting of your magnetic product components.

Whether you need small quantities of prototype parts or production runs, the Westinghouse Metals Plant has the complete metal facilities and experienced engineers to help improve cost and quality of your component parts. For further details on Investment Castings, ask for DB-52-500. Write Westinghouse Electric Corporation, Materials Manufacturing Department, Blairsville, Pa. J-05006

YOU CAN BE SURE...IF IT'S Westinghouse

For more information, turn to Reader Service card, circle No. 479

Magnesium Use Down; Production Up in 1957

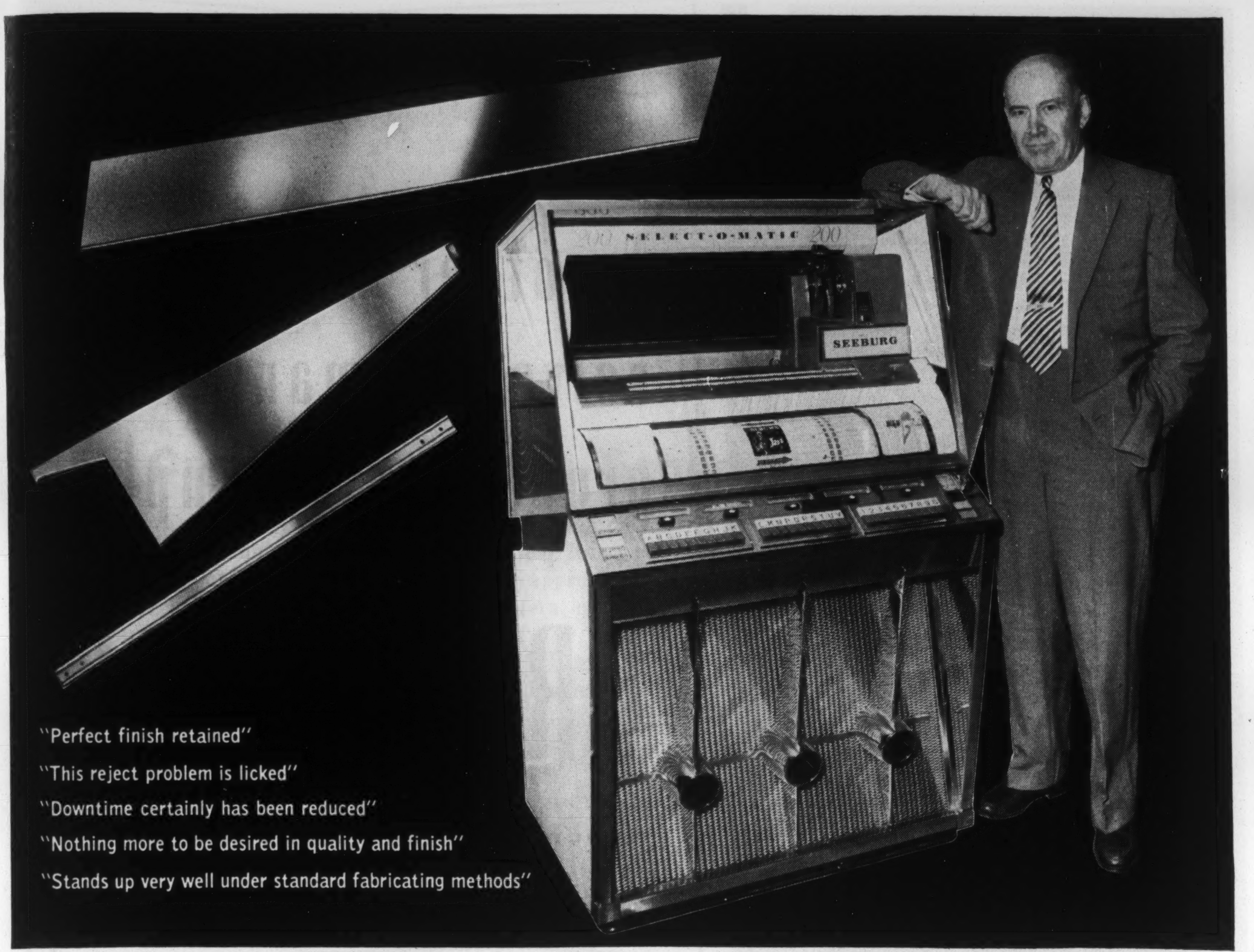
Based on preliminary reports issued by the Bureau of Mines, domestic consumption of primary magnesium in 1957 is estimated at 47,000 tons—a decrease of 12% from the 53,000 tons used in 1956. Production, on the other hand, increased by more than 18%—from 68,000 tons produced in 1956 to 81,000 tons in 1957.

According to the Bureau, a significant portion of the reduction in magnesium consumption can be attributed to the discontinuance of requirements calling for magnesium's use as a reducing agent in the production of titanium. Adjustment of the defense program in mid-year is also said to have had some influence.

Indications are, however, that 1958 will see increased usage of magnesium for structural applications. This prospect is based on technical data published last year which indicate that improvements have been made in casting, rolling, forging, extruding, joining, surface finishing, etc.

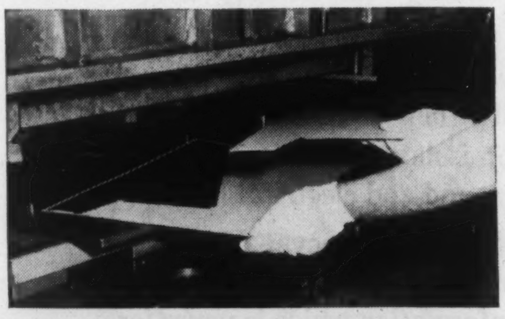
Powder Metallurgy Holding Its Own

The powder metallurgy industry is in a "relatively firm position," according to Kempton H. Roll, executive secretary of the Metal Powder Assn. This statement is based on the fact that 1957 consumption of iron powder (considered to be a bellwether of the entire powder metallurgy industry) amounted to 30,500 tons, or only 6% less than the 32,600 tons produced in 1956. The 6% decrease, Mr. Roll says, compares favorably with Dept. of Commerce reports which indicate that over-all industrial activity in 1957 decreased by approximately 7½ to 8%.

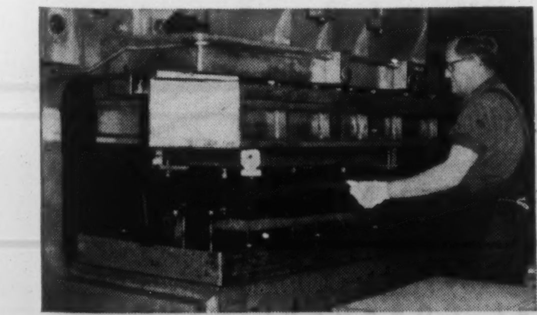

SELECT-O-MATIC 200
SEEBURG
"Perfect finish retained"
"This reject problem is licked"
"Downtime certainly has been reduced"
"Nothing more to be desired in quality and finish"
"Stands up very well under standard fabricating methods"

K. R. Craft, Vice President, The Seeburg Corp., Chicago, with one of the company's famous juke boxes. The brilliant reflectivity and durability of Nickeloid pre-plated metals is an important factor in the product's eye-catching good looks.

NICKELOID METALS SAVE 4 PRODUCTION STEPS—REDUCE REJECTS FOR THE SEEBURG CORPORATION



Standard fabricating methods are used to stamp and form juke box trim. Nickeloid Metals eliminate machinery tie-up; rejects are less than 1%.



Stamping Nickeloid chrome steel, protected with Mar-Not adhesive-backed paper which is easily peeled off. Finished part will need no polishing.

Pre-Finished Design Material is Easily Worked With Standard Fabricating Methods

The Seeburg Corporation uses Nickeloid *pre-plated* chrome steel to achieve functional beauty and attention-value . . . economically. Before switching to Nickeloid, the company did its own cleaning, plating and buffing. The job required four — sometimes five more operations than are now necessary. According to Mr. Craft, "The tremendous cost of plating and buffing was not only more expensive and much more time consuming, but the finished product had to be inspected, and the rejections on plated and buffed metals was very much higher than it is with Nickeloid. Economically, the Nickeloid Metals have proved themselves in production."

Using standard fabricating methods, Nickeloid Metals need only be stamped and formed — then assembled. By capitalizing on this pre finished *method* of production, this leading manufacturer has eliminated the machinery formerly required for plating, polishing and buffing — saved four or five production steps, and is producing a better end product *with less manpower*. Can you use these advantages in *your* operation?

14 finish-to-base metal combinations — sheets, coils, strips.

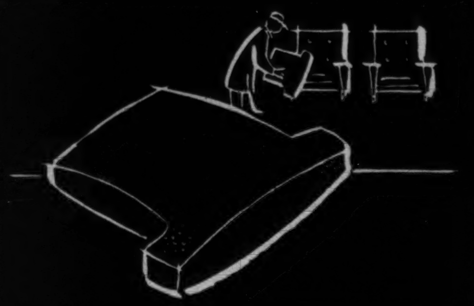
WRITE TODAY FOR FREE LITERATURE

NICKELOID METALS
SINCE 1898

AMERICAN NICKELOID COMPANY
PERU 6, ILLINOIS

For more information, turn to Reader Service card, circle No. 484

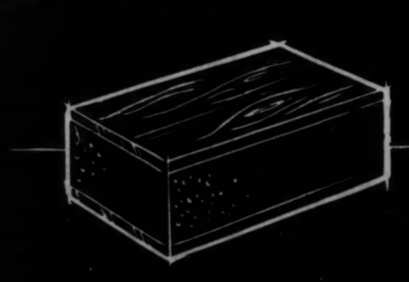
Begin with slab stock. Flexible foams can be cut, sliced, die-cut, sewn, quilted, draped, nailed, hog-ringed. Rigids can be fabricated with woodworking tools.



Or . . . use pre-molded shapes, ready to set in place.

Or . . . foam-in-place by spraying urethanes to adhere to vertical, even overhead planes.

Or . . . pour foam-in-place urethanes to fill voids or encapsulate difficult shapes. Use them in potting or deep casting.



Or . . . use urethanes in strength-with-lightweight sandwich constructions.

No other material solves so many problems so simply as URETHANES!

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Their amazing versatility of form and wide range of usefulness are well matched by the many labor-saving ways urethanes can be fabricated. Only a few of the possibilities are shown here!

However you use them you'll find urethanes easy to handle, economical and full of new design ideas in cushioning, packaging, vibration isolation, shock absorption or insulation against heat, sound and electrical loss.

As suppliers of NACCONATE® Diisocyanates, basic urethane components, our application laboratory has developed much valuable information which is yours for the asking. A brief note, on your company letterhead, outlining your particular interest will enable us to be specific in reply.

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For more information, turn to Reader Service card, circle No. 510

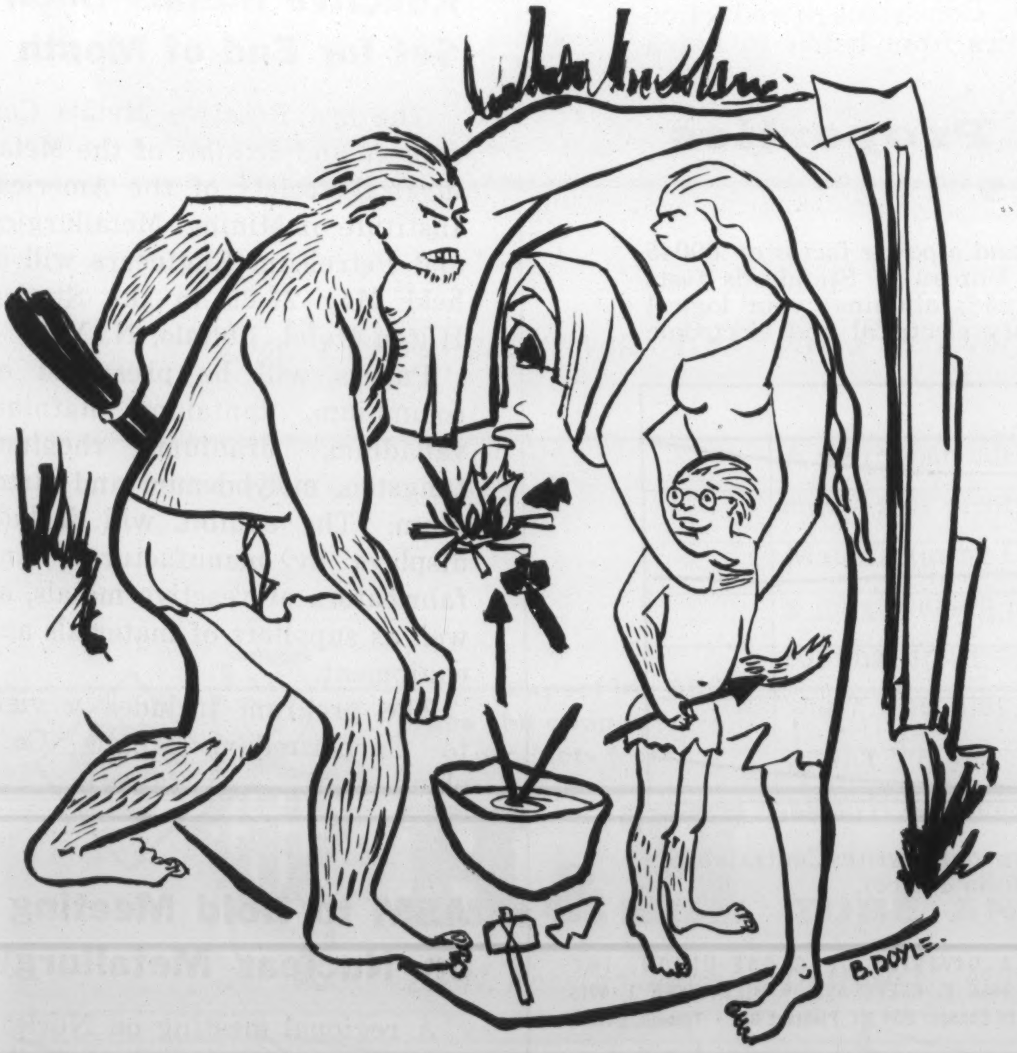
News OF INDUSTRY

1958 Castings Congress Schedules 100 Papers

The 1958 Castings Congress and Foundry Show, sponsored by the American Foundrymen's Society, will be held May 19-23 at the Cleveland Public Auditorium. According to S. C. Massari, AFS technical director, the ". . . purpose of the Castings Congress is to assist world foundrymen to pour castings that will be thoroughly acceptable to the design and materials engineers working in an almost unlimited number of industries."

To achieve this goal, a program including approximately 100 technical papers on virtually every aspect of the castings industry has been planned. Some of the fields to be covered are: Light metals—several sessions devoted exclusively to the interests of die casters and permanent mold founders; gray iron—a session on "Basic Microstructures" and one on "Relation of Mechanical Properties to Microstructures"; malleable iron—a session on "Supplemental Heat Treatment of Pearlitic Malleable"; brass and bronze—a roundtable discussion on "New Developments in Copper-Base Alloy Casting Methods"; sand casting—a paper on "Hot Deformation of Molding Sand."

Also scheduled are special sessions on heat transfer, safety, hygiene, air pollution control, industrial engineering and cost; and three foreign papers: "Influence of Heat on Bonding Properties of Bentonite," by Dr. Franz Hoffman of Switzerland, "Controlled-Slag Hot Blast Cupola," by D. Flemming of the Institute of British Foundrymen, and "Gases in Cast Iron," by L. W. L. Smith of the British Cast Iron Research Assn.



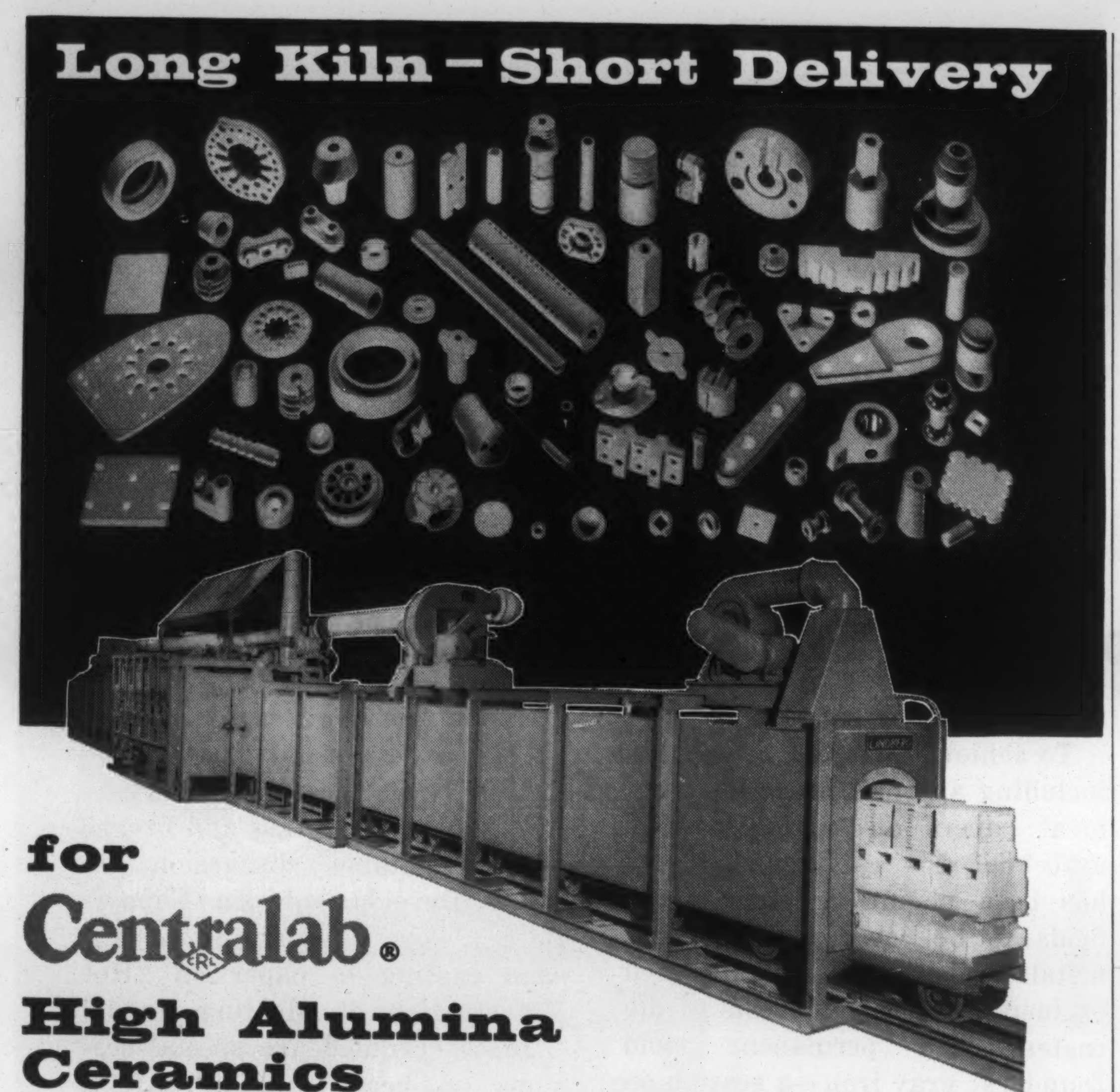
"I don't care. I'm sick of his prattle about precipitation hardening."

Committee on Cermets Established by ASTM

A new study committee on cermets was organized by the American Society for Testing Materials during the Society's Committee Week recently held in St. Louis. According to ASTM, the committee was established ". . . in order to more thoroughly review the field of materials . . . and to make recommendations as to how the Society may keep abreast of developments leading ultimately to the establishment of proper standards."

One of the first problems facing the committee is the selection of a proper definition of the mate-

Long Kiln—Short Delivery



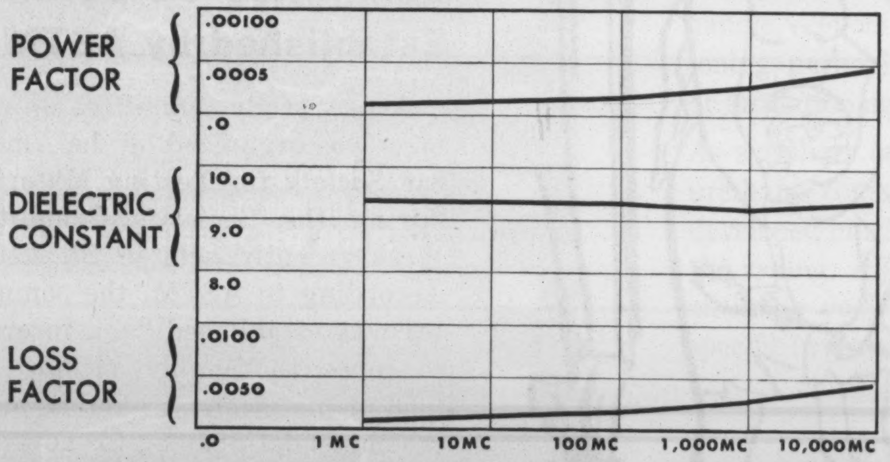
for Centralab®

High Alumina Ceramics

Fast delivery of 95% and 85% High Alumina, to your most critical specifications, is assured by Centralab's new 80 foot continuous kiln. First of its design in the United States, this new kiln is capable of producing 21 tons of exceptional quality High Alumina every month. Consistent reproduction of electrical and physical properties from batch to batch is guaranteed.

Superior Electrical Properties at High Frequencies

Extremely stable dielectric constant and a power factor of .00045 at 9000 megacycles (see graphs of Bureau of Standards tests below) make Centralab Body 206 (95% alumina) your logical choice for all types of high reliability electrical and electronic applications.



For complete specifications and design data write Centralab or consult Sweet's Product Design File (folio 4 a/ce).

Centralab CRL ®
X-5830

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CERAMIC CAPACITORS • ENGINEERED CERAMICS • SEMI-CONDUCTOR PRODUCTS

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rials loosely referred to as cermets. According to ASTM, the selection of an appropriate definition is complicated by the lack of clear-cut definitions of such common terms as "ceramic," "metal" and "alloy." A definition which is being considered by the group is: "A heterogeneous body composed of two or more intimately mixed but mechanically separable phases, of which at least one is metallic and one ceramic."

Initial work of the committee will include 1) the circulation of questionnaires in order to obtain a list of existing standards which might be applicable with or without modification, and 2) the development of a symposium on the properties of cermets.

Reactive Metals Show Set for End of Month

The 3rd Reactive Metals Conference and Exhibit of the Metallurgical Society of the American Institute of Mining, Metallurgical and Petroleum Engineers will be held May 27-29 in the Statler-Hilton Hotel, Buffalo, N. Y.

Papers will be presented on columbium, tantalum, hafnium vanadium, uranium, rhenium, tungsten, molybdenum and zirconium. The exhibit will include displays by manufacturers and fabricators of reactive metals, as well as suppliers of materials and equipment.

The program includes a visit to Carborundum Metals Co.'s plant.

ASM to Hold Meeting on Nuclear Metallurgy

A regional meeting on Nuclear Metallurgy, sponsored by the American Society for Metals, will be held on May 19, in Washing-

It's time to see H & H for a fresh new slant on your tube problems

"Don't know about you 'Rob' but I'm knockin' off for lunch."

A more than adequate engineering staff, long years of experience—plus plenty of imagination—makes H & H Tube and Manufacturing Company a good place to go when you have a tough tubing problem. And there's no better time to look for that fresh approach, than now—in the spring. So why wait? You may be missing out on quality, economies and service you never thought possible. It costs nothing to learn what H & H has to offer. And the time to do it is right *now*.

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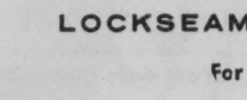
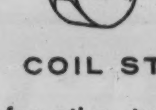
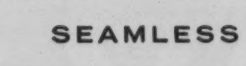
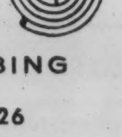

LOCKSEAM


COIL STRIP


SEAMLESS TUBING



TUBULAR PARTS

For more information, turn to Reader Service card, circle No. 426

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I-S SPRINGS

in this dependable

AGASTAT®

time delay relay

—because I-S Beryllium Copper Springs provide—

- **EXCELLENT ELECTRICAL CHARACTERISTICS**
- **COMPLETE FREEDOM FROM FATIGUE**
- **SUPER PRECISION ACCURACY**

AGASTAT* time delay relays are known world-wide for dependability . . . function faithfully in tropic heat and polar cold. The thirteen I-S Beryllium Copper Springs incorporated in the design help maintain the reputation of AGASTAT for exceptional dependability in continuous service. I-S Engineers are widely experienced in designing beryllium copper springs to obtain maximum performance at minimum cost. They will gladly make recommendations for solving your particular problem.

CATALOG AVAILABLE on Beryllium Copper compression springs, flat springs, strip springs, contact strips, contact rings and screw machine parts. Call or write for your personal copy today, or consult Sweets' Product Design File.

**AGASTAT is a registered trade mark of Elastic Stop Nut Corp. of America, 1027 Newark Ave., Elizabeth 3, N. J.*

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ton, D. C. The papers include "Materials Problems in Nuclear Reactors" and "Radiation Effects on Materials." The one-day meeting will include a field trip to the Naval Research Laboratory Reactor.

Further information may be obtained from Mr. N. C. Fick, general chairman, 836 24th St., S., Arlington, Va.

NYU Offers Symposium on Reactor Materials

A special symposium on "Materials for Nuclear Reactors" has been planned by the Dept. of Metallurgical Engineering, New York University, for the week of June 9th. Some of the topics scheduled for discussion are: nuclear physics; general materials considerations; ceramics and graphite; zirconium and beryllium; corrosion—aluminum, zirconium, stainless steel and uranium alloys; design considerations; and trends in reactor development.

For further information, contact C. G. Goetzel, Senior Research Scientist, Dept. of Metallurgical Engineering, College of Engineering, New York University, University Heights, New York 53, N. Y.

Engineers

William H. Mutschler has been appointed chief engineer, Pittsburgh Works, Allis-Chalmers Mfg. Co.

A. J. Talamini, has been named director of engineering, Electro Tec Corp.

John G. Booth has been appointed general manager, Davies Laboratories, Minneapolis-Honeywell Regulator Co.

George A. Gibbs is now chief metallurgical engineer and chemist in charge of plant production and

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SAW STEELS

Sharon metallurgists have for the past decade concentrated on the development of better saw steels. As a result, they have established an industry-wide reputation for steels with a balance of toughness and hardness to absorb maximum punishment without fracturing or dulling.

It will pay you to contact your Sharon salesman and get the facts on these durable, edge-holding steels for saws or any cutting tool or implement.

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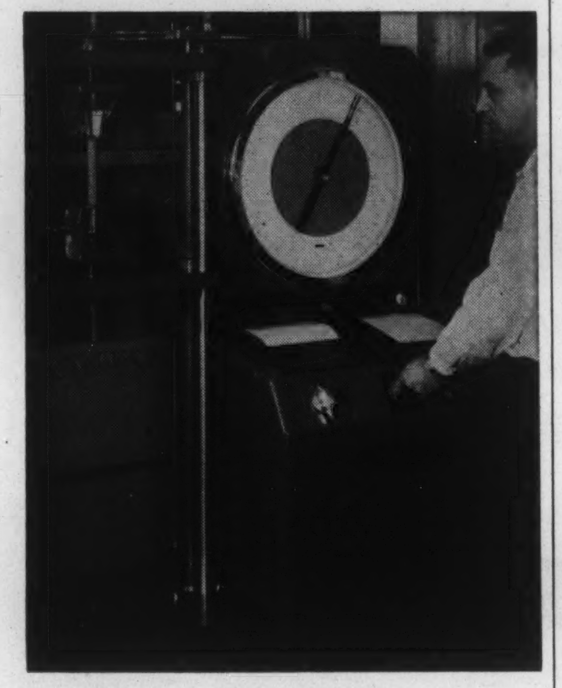

Exacting physical requirements such as fatigue resistance, tensile strength and drawing properties are easily met by SOMERS, where complete facilities include a modern laboratory equipped for chemical, electrical and performance testing of all SOMERS THINSTRIP—both in process and before shipping.

The latest electronic gages, controls and other precision instruments guarantee uniform quality every time in nickel and its alloys from .020" and copper and its alloys from .010", both down to .000175".

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News OF INDUSTRY

quality control, L-S Plate and Wire Corp.

John P. Klembeth has been appointed product engineering manager and **Richard A. Bennett** chief mechanical research and development engineer, Milton Roy Co.

Dr. Nat C. Robertson has been appointed general manager, research and development, Spencer Chemical Co.

Austin L. Stowell has been appointed to the newly created position of director of product research, and **Robert F. West** has been named director of product engineering, Stanley Tools, a division of Stanley Works.

George D. Cowie has been named assistant chief engineer, Plymouth Div., Chrysler Corp.

Gustaf A. Wallenstrom has been appointed to the newly established position of consulting engineer, Technical Products Dept., General Electric Co.

Edward E. Kirkham has been named chief development engineer and head of the experimental dept., Machinery Div., Pratt & Whitney Co.

Murray Kanes is now director of engineering, Friez Instrument Div., Bendix Aviation Corp.

Dr. J. W. Luthy has been named director of applications, Dyestuff and Chemical Divs., Sandox, Inc.

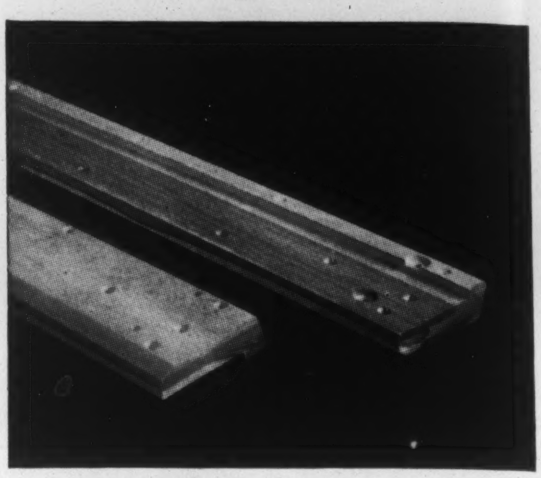
Otmar E. Teichmann has been appointed associate director of engineering at Borg-Warner Corp.'s Des Plaines, Ill. center.

T. E. Veltfort, managing director of the Copper and Brass Research Assn., has been elected chairman of the Standards Council, American Standards Assn.

Donald O. Swan has been named general manager of the Petroleum Specialties Dept., a newly formed corporate department of Esso Standard Oil Co.

Dr. Joseph V. Petrocelli has been appointed head of the electrochemical

WHAT'S YOUR WOOD PROBLEM?



Gamble research helps improve CONVEYORS!

THE PROBLEM. Conveyor deflector bars have to be tough enough to withstand the repeated impact of conveyed objects. If they're not, the bars break in the middle or split horizontally. In either case, the result is production equipment downtime as well as maintenance expense.

THE RESULT of Gamble testing and development: a laminated hickory deflector bar that is actually thinner than the old solid-wood "problem" bars. Lamination assures *more uniform* strength (little chance of weakest parts of individual pieces lining up). Hickory assures *greater* and *more consistent* strength. New thinness assures *greater resiliency.* They all add up to longer conveyor life . . . less time spent in downtime for repairs. Perhaps Gamble could help with *your* wood problem.

Send for FREE booklet Illustrating GAMBLE services

Solving Problems in Wood
the GAMBLE STORY

This 28-page booklet describes Gamble facilities and services in detail. Includes many photographs of unusual products designed, tested and perfected by Gamble Brothers. Write for your copy today! Gamble Brothers, Inc., 4627 Allmond Avenue, Louisville 9, Ky.

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Louisville 9, Kentucky
If the problem involves WOOD —GAMBLE can help!

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Get the best out of Teflon®
with this flexible hose...

completely corrosion-proof

- **Chemically inert from end to end —** non-contaminating and universally useful
- **Flanged ends —** liner covers full gasket face for continuous protection
- **Unaffected by corrosive fluids —** special compound of Teflon developed for maximum life

Here's a hose exclusive on two counts. (1) It has *flanged ends* – the first fluorocarbon hose to have them. (2) It has the patented Fluoroflex®-T tube.

Tube extends to cover the full gasket face of the flange, forming a continuous and integral assembly of hose and flanges. Fluid cannot contact metal. Eliminates need for costly alloy fittings.

Cleaning problems are simplified, too. The smooth, continuous bore prevents entrapment of materials.

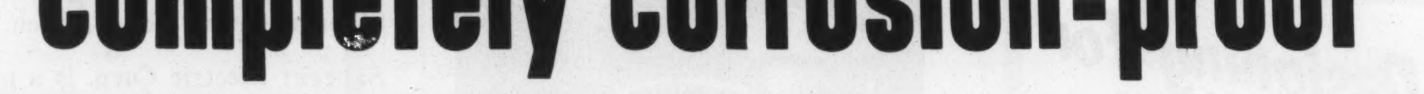
A special, high-density, non-porous compound of virgin Teflon, Fluoroflex-T is completely inert to virtually all known chemical and corrosive solutions, solvents and gases to 500° F. Write for data.

RESISTOFLEX CORPORATION, Roseland, N.J.
Other Plants: Burbank, Calif.; Dallas, Tex.

® Fluoroflex is a Resistoflex trademark, reg., U.S. pat. off.
® Teflon is DuPont's trademark for TFE fluorocarbon resins

RESISTOFLEX

Complete systems for corrosive service



LINED STEEL PIPE • FLANGED FLEXIBLE HOSE • BELLOWS • ELBOWS • TEES • REDUCERS • DIP PIPES & SPARGERS • LAMINATED PIPE

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For more information, turn to Reader Service card, circle No. 390

Transistors Subjected to Heat, Cold and Humidity

. . . in this Cincinnati Sub-Zero Environmental Test Unit.

Custom-built to specifications, a new model SU-40-8-HC Cincinnati Sub-Zero test unit is providing vital product data at Federal Telecommunications Laboratories, Palo Alto, California. Used to test transistors and other electronic components, it is adjustable from minus 50° to plus 200° F., while maintaining a relative humidity of 95% between plus 80° and 160° F. Compact and portable, it is ideally suited for a variety of test applications.

Model SU-40-8-HC

If you must have specific product reaction data at various temperatures, altitudes, humidities, etc., outline your requirements to us for a no-obligation recommendation on a unit built to your needs.

'58

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Designing for LOWER production costs

5 PARTS FOR THE PRICE OF 1

The use of Precision Investment Casting can simplify many design problems — and, at the same time, *make lower production costs possible.*

Here is an example of how one manufacturer now produces five control cylinder housings for his former cost to produce one.

Through the Precision Investment Casting process, 22 separate set-ups and more than 30 different machine operations formerly required to produce these control cylinder housings were reduced to 5 machine operations.

The advantages of Precision Investment Casting are many. Not only can it frequently save money in production costs, it also allows the use of harder alloys adding a distinct selling feature to the machine: *longer life.*

Write for the full story of Precision Investment Casting today. In it you may find the solution to some of your design or production problems.

*Details on request.

Send for our latest 12-page booklet, "Modern Precision Investment Casting." It gives you full details of the "how and why" of Investment Casting.

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Photo and data courtesy of Precision Metalsmiths, Inc.

For more information, turn to Reader Service card, circle No. 520

section of International Nickel Co.'s Research Laboratory, Bayonne, N. J.

E. Leonard Borg has been named manager, synthetic rubber development, Naugatuck Chemical Div., U. S. Rubber Co.

Fred Kohler has been appointed director of research and **Chester A. Tudbury** chief engineer, New Rochelle Tool Corp.

Everett Gravenhorst is now director of engineering, Fluid Systems Div., Waldorf Instrument Co.

Richard A. Shaw has been named chief engineer, Neff Instrument Corp.

Companies

Superior Tube Co. has completed its new million dollar plant in Wapakoneta, Ohio.

Gardner-Denver Co. has established two new metallurical laboratories, one at its Quincy, Ill. plant and the other at Grand Haven, Mich.

Sargent Electric Corp. is a new division of **Pyramid Instrument Corp.**

W. W. Cash Co. has moved its offices to a new building at 115 S. Main St., Decatur, Ill.

Crucible Steel Co. of America has acquired **Rem-Cru Titanium, Inc.** from Remington Arms Co.

Curtiss-Wright Corp. has moved its Industrial and Scientific Products Div. to Rte. 533, Quaker Bridge Rd., Princeton, N. J.

Fullerton Mfg. Corp. is the sixth and newest member of **Franklin Research Corp.**

Mercast Corp. has acquired **Gray & Huleguard, Inc.,** suppliers of equipment for use in missiles, jet aircraft and electronic devices.

Isochem Resins Corp. is the name of Isochem Corp.'s new affiliate.

Morningstar, Nicol, Inc. and its subsidiary, **Paisley Products, Inc.,** have been merged to form a single corpo-

(continued on p 209)

PLAST-IRON POWDERS

NEW

Grade B-280

Reduced • 80 Mesh

Improved Sponge Iron Powder

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Complete Interchangeability For Present Dies

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Competitively Designed

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PM PLASTIC METALS

PLASTIC METALS

Division

National-U.S. Radiator Corporation

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JOHNSTOWN, PA.

For more information, circle No. 490

Companies—cont'd from p 204

ration to be known as **Morningstar-Paisley, Inc.**

Chicago Molded Products Corp. has inaugurated the Bachner Award, to be presented for "outstanding contributions to the practical applications of plastics."

American Standard Co.'s Atomic Energy Div., has moved its offices to 369 Whisman Rd., Mountain View, Calif.

Rogers Corp. has formed a new division which will concentrate on high temperature materials for application in missiles and rockets.

Cohu Electronics, Inc. has acquired **Millivac Instrument Corp.** and **Volkers & Schaffer, Inc.** The two will be formed into a single operating unit to be known as Millivac Div.

Foster Wheeler Corp. has moved its New York offices to 666 Fifth Ave., New York 19, N. Y.

General Machine Products Co., Inc. has moved to a new 60,000-sq-ft plant situated adjacent to the Philadelphia Interchange of the Pennsylvania Turnpike in Trevose, Pa.

M&C Nuclear, Inc. is the name of a wholly owned corporate subsidiary formerly known as Nuclear Products Div., Metals & Controls Corp.

Neilson Chemical Co. has moved to new quarters at 2300 Gainsboro, Detroit 20, Mich.

Minnesota Rubber Co. is the new corporate name of **Minnesota Rubber and Gasket Co.** The company's subsidiaries have been centralized and given divisional status within the parent organization.

LeMaire Machine Tool Co. is the new name of **LeMaire Tool & Mfg. Co.**

Champion Paper and Fibre Co. has acquired half ownership of **NRC Vaculite Corp.**, a subsidiary of National Research Corp.

Tipptronics, Inc. has transferred its operations to Chagrin Falls, Ohio.

Texsteam Corp., a subsidiary of **Vapor Heating Corp.**, has purchased

PLAST-IRON POWDERS

NEW

Grade A-213

Electrolytic 100 Mesh

Non-Laminating Electrolytic Iron Powder

•

Presses to Ultra-High Densities in One Operation

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Division

National-U.S. Radiator Corporation

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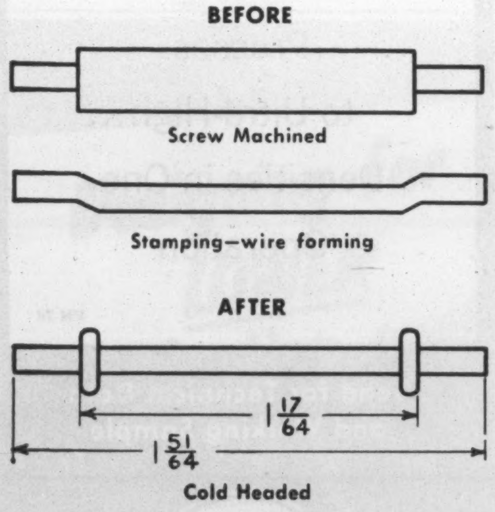
COST REDUCTION PROGRAM CALLS FOR COLD HEADING

Hassall Re-Design Often Means Big Savings on Parts

The most important consideration we can point out to the designer or purchaser of fasteners and small parts is that any part which can be machined from rod stock is also potentially available from the cold heading manufacturer. This technique offers speed of production, without scrap loss, plus superior strength and appearance for low cost and high design efficiency.

Perhaps our greatest contribution to your operation is our re-design service. An expert cold heading designer can very often study your drawings and come up with a modified part which will be lower in cost, stronger structurally, and easier for you to assemble.

This spacer is typical of such a Hassall re-design. Note the customer's drawing . . . this is a stamping, not too accurate, with poor bearing surfaces and not too easy to handle in assembly.


BEFORE
Screw Machined
Stamping—wire forming
AFTER
1 17/64
1 51/64
Cold Headed

Now, look at this spacer as re-designed for cold heading. Now, a double collar spacer which is very accurate, structurally much stronger, and with much better bearing surfaces. And lower in cost!

Given complete specifications, including a drawing and an idea of the application, we can quickly tell you whether or not it will be advantageous to have your part or fastener JOB-DESIGNED by HASSALL.

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Manufacturers Since 1850

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News OF INDUSTRY

the assets of **Graham-Lemunyon Corp.**

Pittsburgh Plate Glass Co. will construct a new multi-million dollar continuous fiber glass yarn plant at Shelby, N. C.

Societies

American Foundrymen's Society will give awards to the following men at the 1958 Foundry Show and Congress to be held May 19-23: Ralph A. Clark, Electro Metallurgical Co.; Howard J. Rowe, Aluminum Co. of America; William W. Maloney, American Foundrymen's Society; Mervin H. Horton, Deere & Co.; Kenneth H. Priestley, Vassar Electroloy Products, Inc.; Franklin B. Rote, Albion Malleable Iron Co.; Frank S. Brewster, Brumley-Donaldson Co.; Ernest T. Kindt, Kindt-Collins Co.; and Fred G. Sefing, International Nickel Co.

National Screw Machine Products Assn. has elected to membership the following companies: Affiliated Screw Products Co., All Thread Products Co., Beacon Metal Mfg. Co., Gillette Safety Razor Co., Horton Co., Kinroth & Son Mfg. Co., Solt Automatic, Stewart-Warner Corp., Vanamatic Co. and Walrod Machine Products, Inc.

Structural Clay Products Institute has elected the following officers: president — Kenneth W. Dunwody, Cherokee Brick and Tile Co., vice president—Paul B. Belden, Jr., Belden Brick Co.; treasurer — George Gammie, Illinois Brick Co.; secretary —Joseph J. Cermak, SCPI staff; and chairman of the board and general counsel—Douglas Whitlock.

(News of Meetings on p 212)

USE THE 'SELECTOR'—You will find properties of most engineering materials, plus names and addresses of suppliers, in M/DE's *Materials Selector* reference issue, published last September.

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Form the shape you want with USS Galvanized Steel Sheets

—the zinc stays on

A garbage can lid starts out with a real wallop and has a tough life in front of it. This press at The F. H. Lawson Company in Cincinnati, Ohio, turns out thousands of them from USS Galvanized Steel Sheets.

What's important to The F. H. Lawson Company, and the folks who buy garbage cans, is that the protective zinc coating stays on, providing a finished product, fully protected.

You can get the same results with USS Galvanized Steel Sheets.

Call our local sales office or write to U. S. Steel Corporation, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

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At long last you can now secure beautifully bright, gleaming colors from a simple LUSTER-ON chromate dip process for your zinc plated small parts.

These are not just spotty identification colors. These are scintillating golds, yellows, blues, greens, violets, reds, brass and copper hues that will add glamor and sales appeal.

Especially Brilliant on Wire Goods

Be the first in your field to offer this sales booster. Write or wire today for the full story on low-cost LUSTER-ON COLOR.

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News OF INDUSTRY

Meetings

Industrial Heating Equipment Assn., semi-annual meeting. Hot Springs, Va. May 18-21.

National Assn. of Metal Finishers, annual meeting. Cincinnati. May 19-21.

Nonferrous Founders Society, annual meeting. Cleveland. May 19-21.

American Electroplaters' Society, annual convention. Cincinnati. May 19-22.

62nd Castings Congress and Foundry Show, American Foundrymen's Society. Cleveland. May 19-23

American Iron & Steel Institute, annual meeting. New York City. May 21-22.

Electronic Industries Assn., annual meeting. Chicago. May 21-23.

Reactive Metals Conference, American Institute of Mining, Metallurgical & Petroleum Engineers. Buffalo. May 27-29.

American Gear Manufacturers Assn., annual meeting. Hot Springs, Va. June 1-4.

National Telemetering Conference and Exhibit, American Institute of Electrical Engineers, American Rocket Society, Instrument Society of America and Institute of Aeronautical Sciences. Baltimore. June 2-4.

American Rocket Society, Inc., semi-annual meeting. Los Angeles. June 8-11.

Society of Automotive Engineers, summer meeting. Atlantic City. June 8-13.

Malleable Founders' Society, annual meeting. Hot Springs, Va. June 9-10.

American Society of Mechanical Engineers, semi-annual meeting. Detroit. June 15-19.

Alloy Casting Institute, annual meeting. Hot Springs, Va. June 21-24.

American Society for Testing Materials, 61st annual meeting and apparatus exhibit. Boston. June 22-28.

American Institute of Electrical Engineers, summer general meeting. Buffalo, N. Y. June 26-27.

Society of the Plastics Industry, Inc., Midwest section conference. French Lick, Ind. June 26-27.

STRAITS TIN REPORT

MALAYAN TIN BUREAU

New developments in the production, marketing and uses of tin

The Fish and Wildlife Service of the U.S. Department of the Interior has reported that "packaging frozen fish in tin results in superior storage life." Only tin prevents the deteriorating action of seeping oxygen on frozen fish in cold storage over a period of months.

Considerable laboratory progress has been made in the electroplating of tin as a bright coating through the addition of certain wood tars to the electrolyte. Some observers feel there is a distinct possibility that this bright tin plating may take the place of metal polishing in many applications throughout the metal industry.

A new machine has been designed in England to help speed up mass production soldering. It consists of an electrically heated solder bath with motor-driven pump to provide a stationary wave of fresh solder, which is exposed to moving printed circuit boards.

★ ★ ★

An invention was recently patented which is expected to lengthen the life of heavily stressed bearings from a few weeks to several years. A mesh of tinned wire is embedded just below the surface of babbitted bearings before pouring . . . to prevent movement in the bearing surface leading to fatigue, cracking and spalling.

Ask us to send you TIN NEWS, a monthly letter. It will keep you posted on tin supply, prices, new uses and applications.

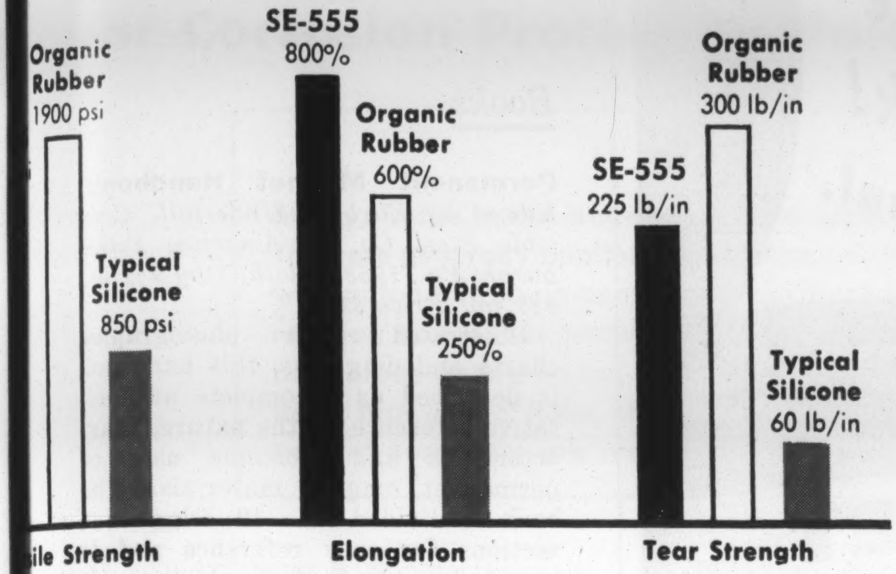
The Malayan Tin Bureau
Dept. 24E, 1029 Connecticut Ave., Washington 6, D.C.

For more information, circle No. 497

For more information, circle No. 521 ➤

HOW TO SOLVE PRODUCT DESIGN PROBLEMS WITH

SILICONE IDEAS

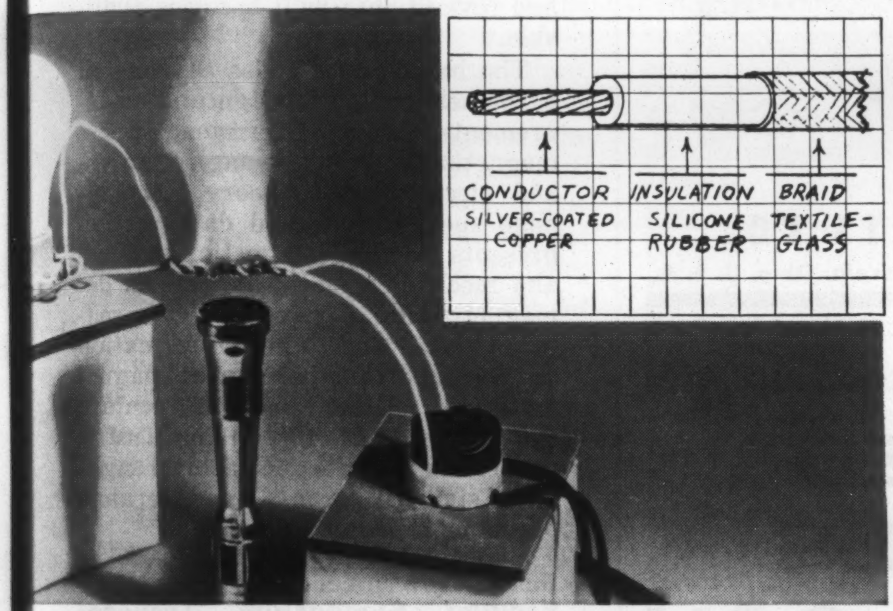


Problem: *Organic rubber parts failing because of temperature extremes and ozone. High tear and tensile strength cannot be sacrificed.*

Solution: Replace with SE-555—silicone rubber with tear and tensile strength comparable to organic rubber.

SE-555 is a new silicone rubber with tear and tensile strength double that of ordinary silicone rubber (see comparative typical values at left). Whenever maximum resistance to weather and temperature extremes (minus 150°F to 500°F) is required, combined with high tear and tensile strength, specify SE-555. This is the only material available to rubber fabricators that meets AMS 3345 requirements for tear and tensile strength, elongation, heat resistance, compression set and low temperature flexibility. SE-555 can be fabricated in practically any color, including white.

You can order high strength silicone rubber parts immediately because SE-555 is available from stock for shipment to your fabricator. For more information and a list of qualified fabricators, mail the coupon below.

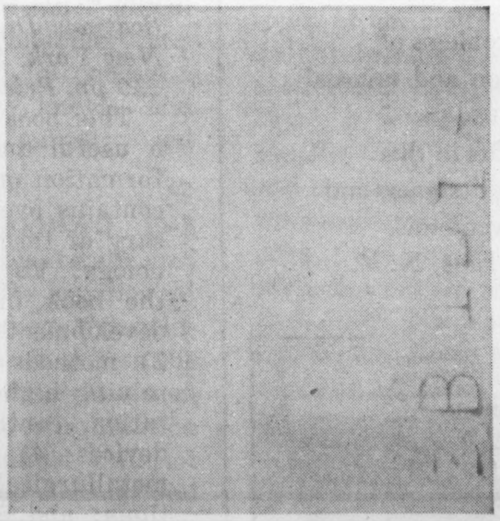


Problem: *Find a wire insulation to withstand extreme conditions of temperature, moisture and ozone.*

Solution: Wire insulated with G-E silicone rubber.

Exposed to an 1800°F flame for hours, G-E silicone rubber insulation forms a non-conducting ash which still insulates. No toxic fumes are released, nor will it shrink and expose the conductor, as the laboratory demonstration on the left shows. Silicone rubber has superior dielectric strength at high temperatures and keeps it for years. It has unparalleled ozone resistance, stays flexible down to minus 75°F or lower. Use silicone rubber insulated wire wherever temperatures are extreme, and where an extra safety margin is needed. Examples: aircraft wire, Class B and H motor and apparatus lead wire, electronic hook-up wire and control cable. Want more information? Send in coupon below.

el coated with an alkyd alumi-
subjected to 1000°F for 2 hours.



Carbon steel coated with silicone aluminum finish, subjected to 1000°F for 24 hours.

Problem: *Extend the life and appearance of metal surfaces designed for high temperature operation.*

Solution: Special paints made with G-E silicones.

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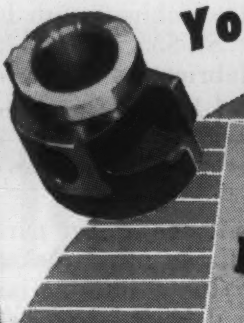

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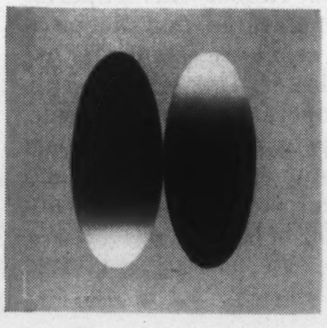

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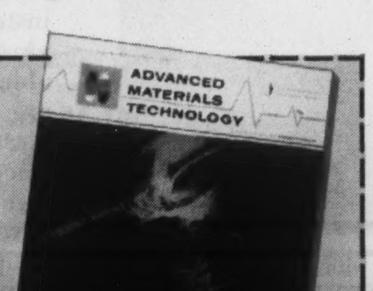

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TECHNICAL LITERATURE

(cont'd from p 45)

Books

Permanent Magnet Handbook. *Edited by Earl M. Underhill. Crucible Steel Co. of America, Pittsburgh, Pa., 1958. Cloth, 8 by 9½ in., 380 pp. Price $10*

Illustrated with photographs, charts and diagrams, this handbook is described as a complete authoritative reference on the nature, characteristics and economic uses of permanent magnet materials. The book is divided into 12 color-coded sections for easy reference and is bound loose-leaf style so that its purchasers may add supplemental and revised data as it becomes available.

The handbook includes sections on permanent magnet design and measurements, theory of ferromagnetism, magnetization and demagnetization, and electromagnet theory. A 125-page specifications and data section presents nominal magnetic, physical and mechanical data, as well as demagnetization curves, energy product values, and other information for all important permanent magnet materials. Other sections contain information on the manufacture, properties and uses of cast, wrought and sintered iron, and ceramic permanent magnet materials.

Vacuum Symposium Transactions: 1956. *Edited by E. S. Perry and J. H. Durant. Symposium Publications Div., Pergamon Press Inc., New York, 1957. Cloth, 8½ by 11 in., 240 pp. Price $12.50*

This book is designed to serve as a useful and current source of information on vacuum technology. It contains over 40 papers and a glossary of terms used in vacuum technology. Various subjects covered in the book include: 1) fundamental developments in vacuum technology; 2) methods and techniques for obtaining high vacuum; 3) instrumentation, controls and other vacuum devices; 4) vacuum distillation; 5) metallurgical and chemical applications; and 6) technical subjects of current interest.

High Strength High Temperature Materials for Standard Parts Symposium. *National Standards Assn., Washington, D. C., 1957. Paper, 8½ by 11 in., 400 pp. Price $7.50*

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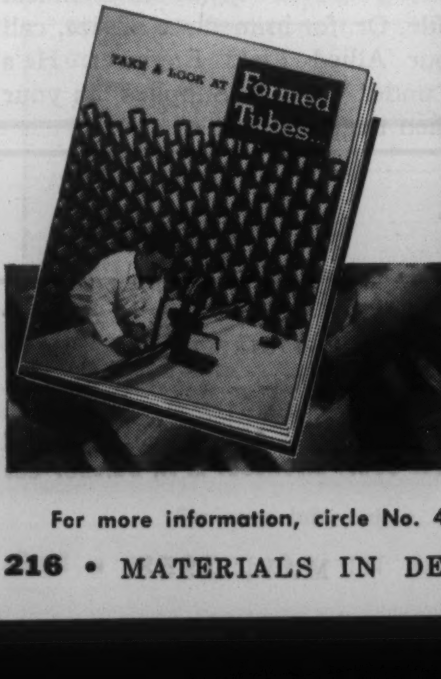

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TECHNICAL LITERATURE

for standard aircraft parts, the various papers given in this book discuss: 1) nickel-base alloys for aeronautical applications, 2) titanium alloys, 3) martensitic high strength high temperature steels, 4) precipitation hardening steels, 5) specialty superalloys, 6) properties, fabrication and surface protection of martensitic 5% chromium steel, 7) frictionless bearings and lubricants, 8) structural and mechanical joints in piloted and pilotless aircraft, and 9) high strength high temperature fasteners. Each paper is well illustrated with charts and graphs, and contains a bibliography.

Reports

Strength of welds EVALUATION OF WELDED JOINTS BETWEEN AISI 347 STAINLESS STEEL AND 70-30 COPPER-NICKEL ALLOY TUBES UNDER THERMAL SHOCK-SPECIMEN NO. 3. *W. F. Claυtice and R. W. Stevens, U. S. Naval Engineering Experiment Station. May '55. 49 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price $1.25 (PB 121877)*

Weather resistant coatings FIFTEEN YEAR EXPOSURE TEST OF PORCELAIN ENAMELS. *Dwight G. Moore and William N. Harrison, National Bureau of Standards. Oct '57. 13 pp. Available from Superintendent of Documents, Government Printing Office, Wash. 25, D. C. Price 15¢ (Report No. 148)*

Describes results of a 15-year exposure test in which porcelain enamel samples were exposed to four climatic conditions representative of different parts of the eastern United States. Enamels affected least were those having high resistance to acid attack.

Soldering aluminum SOLDERING ALUMINUM. *1957. 36 pp. Available from Aluminium Development Assn., 33 Grosvenor St., London, W.1, England. Price 28¢ (Bulletin No. 23)*

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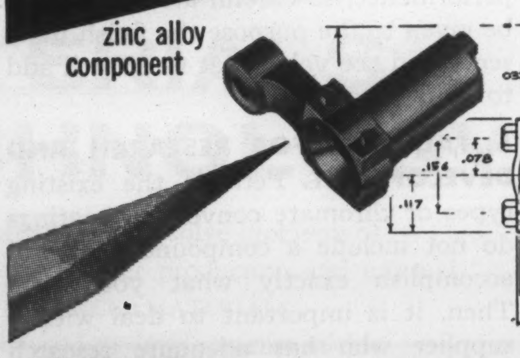

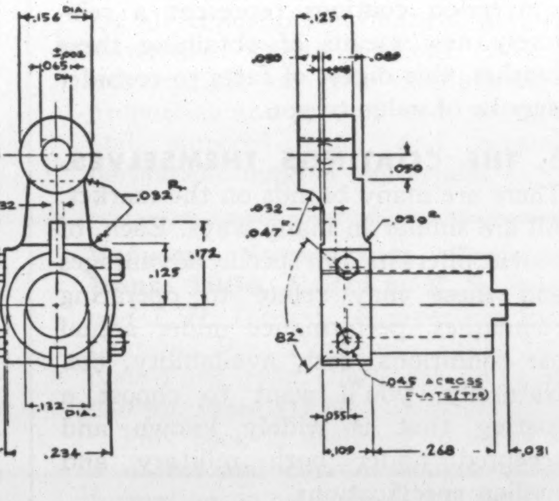

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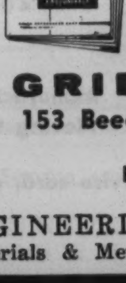

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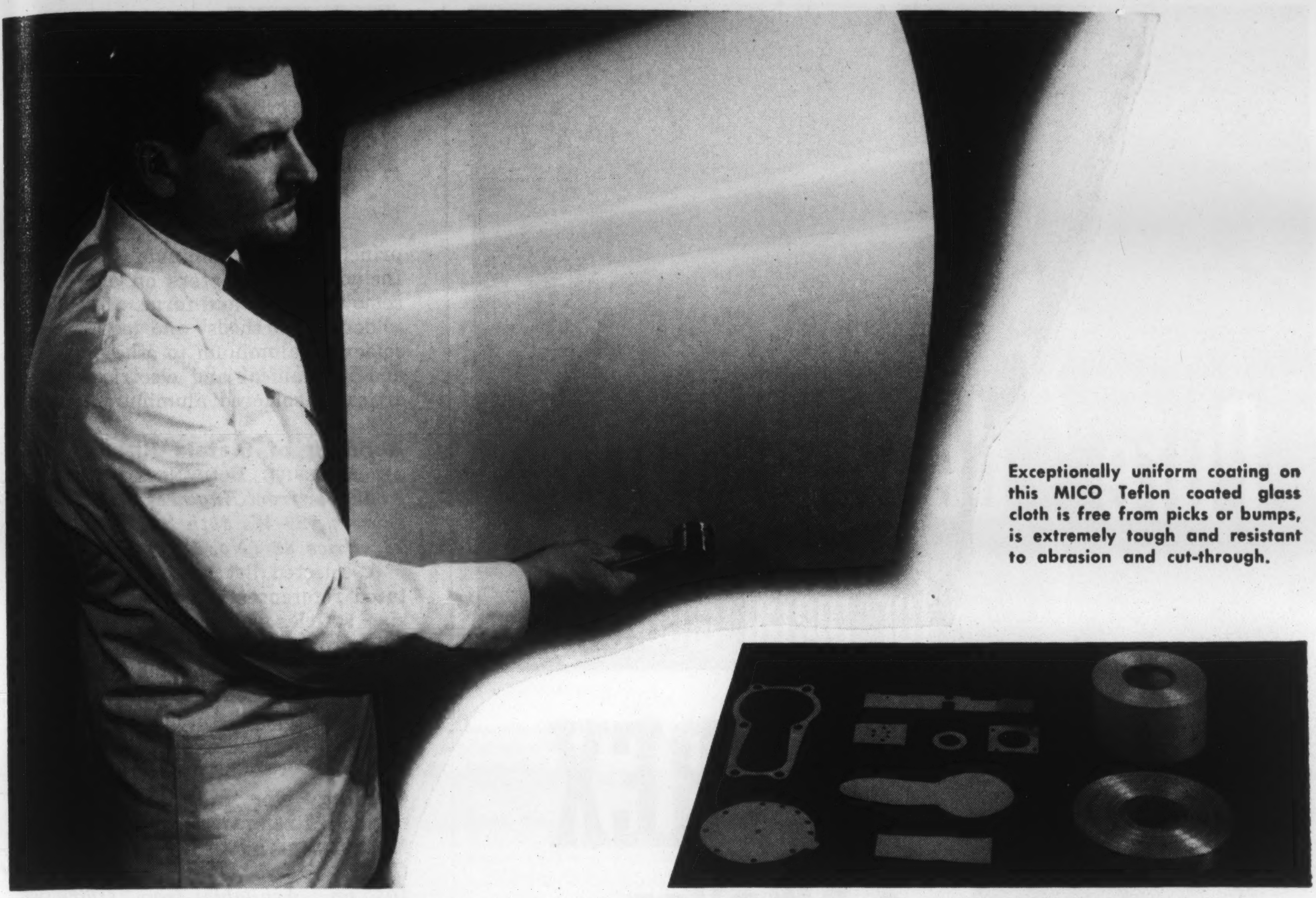

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Bonding of metals BIBLIOGRAPHY ON ADHESIVE BONDING OF METALS. *Available from Engineering Societies Library, 29 W. 39th St., New York 18. Price $2 (No. 12)*

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Coatings for molybdenum OXIDATION RESISTANT COATINGS FOR MOLYBDENUM: PART 3. *D. V. Doane, Climax Molybdenum Co. Apr '57. 104 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price $2.75 (PB 131368)*

Evaluates ductility, oxidation and heat resistance, ballistic impact strength and erosion of unalloyed molybdenum and 0.5% titanium molybdenum alloy coated with aluminum - chromium - silicon sprayed metal coating, nickel-chromium-boron sprayed metal coating, nickel cladding, electroplated chromium and electroplated chromium-nickel composite.

Titanium sandwich structures STAINLESS STEEL AND TITANIUM SANDWICH STRUCTURES. *W. J. Lewis, G. E. Faulkner and P. J. Rieppel, Battelle Memorial Institute. Aug '57. 39 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price $1 (PB 121633)*

Survey of published literature and Government research reports on stainless steel and titanium sandwich structures. Information on companies fabricating and developing sandwich structures, and a discussion of fabrication techniques.

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THE LAST WORD

by H. R. Clauser, *Editor*

Brainstorming Kicks Up a Storm

For several years now, brainstorming has enjoyed a "good press." Nothing but praise was heard for this organized, group approach to so-called creative thinking. Partly as a result of the publicity its use was extended far beyond what it was originally intended for, and many jumped to the conclusion that it could replace systematic and logical reasoning.

Now reaction against brainstorming has set in. The anti-brainstormers (using systematic reasoning, of course) claim to have found that brainstorming actually hinders rather than aids problem solving. Before the argument is settled, if it is ever settled, I'm afraid that there will be a lot of unclear thinking about thinking on both sides of the dispute.

To clarify my own thinking on thinking, I dug up a copy of the outline on problem solving I prepared for readers of this column about a year ago. It lists what are generally considered to be the elements involved in thinking and problem solving. They are:

1. Recognizing and defining the problem.
2. Gathering facts pertinent to the problem.
3. Formulating tentative solutions.
4. Evaluating the tentative solutions.
5. Drawing conclusions or deciding on the solution.

Actually, brainstorming applies to only one step in this problem solving process, and that is step No. 3, in which tentative solutions, ideas, and hypotheses are generated. I think when it is understood that brainstorming can serve only as an idea-producing technique and that systematic reasoning is still required for the other steps, much of the heat in the present arguments will be dissipated.

Plastics Autos to Match

What will the French think of next? The sports car (de Pontac) you see in the photo at the end of this column has a plastics body with a flowered fabric molded in to match the lady's dress. Apparently the maker of this car is trying to outdo his American competitors by persuading his customers to change cars every time the wife or girl friend changes her dress.

Up in the Air with a Thermocouple

It is no secret that jet engine builders have been working at the limits of our toughest engineering materials. Just how close to the limits we did not fully realize, however, until a friend directed our attention to the "overtemperature limit" chart for GE's J-47 engine. When the temperature of the J-47's exhaust gas is 1330 F, the turbine wheel has "infinite" life; if the temperature climbs 50 deg to 1380 F, the wheel and the engine will fail in 2¼ min. You can see why a jet pilot likes to have a good, dependable thermocouple in the exhaust stream and an aggressive warning signal on his control panel.

Revue Generale Du Caoutchouc